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DR. FRANKLIN: FRIEND OF THE INDIANS.*

BY

JULIAN P. BOYD, Litt.D.

Librarian, Princeton University

Shortly after Franklin's death in 1790 the Abbé Morellet published in the *Gazette Nationale* a series of Franklin anecdotes which the great diplomat had used to charm his circle of admirers in France. One of them concerned the mental processes of the American Indians. According to Franklin, the savages never traced or desired to trace the connection between cause and effect. An Indian came to see Franklin in Philadelphia to witness the experiment of lighting brandy with an electric spark. When he had seen it, he neither exhibited surprise nor gave any evidence of reflection on the cause, but merely remarked: "These white men are clever rascals."

This anecdote, if Morellet has reported Franklin correctly, may be interpreted in two ways and both ways have significance. It may be taken to indicate that Franklin really did not understand the Indians. To accept this interpretation we must believe that one of the wisest of men, whose greatness was due largely to his understanding of the complex humanity of civilized society, failed completely to understand the simple and childlike nature of the forest inhabitants. The

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second interpretation is more important. The anecdote may be taken as an indication of the intellectual approach of Franklin as well as of that of the Indian. The Indian, schooled by habit not to betray emotion or surprise, probably went back to his village and pondered for days over what to him was a supernatural phenomenon. Franklin, busy with cause and effect viewed in a natural light, was concerned with the immediate and practical application of his laboratory experiment. If the primitive brain of the Indian was limited to ponderings over a supernatural phenomenon, the powerful mind of Franklin was limited to the immediate use of a new instrument. He did not soar into metaphysics, whether contemplating electricity or society. He left no great legacy of systematic thought to the world, as did Rousseau. Rousseau contemplated the American Indian and created a great school of romantic political thought, a systematic ideology that turned a world upside down. Franklin regarded the Indian, as he did everything else, with profound interest. But he did not bother to draw out of the forest society any abstract philosophy for the government of civilized society. He used his knowledge of the Indian for more immediate objectives. This is the key to Franklin's attitude toward the Indian, as it is the key to the working of his mind in the realm of science, politics, diplomacy, and literature.

Two of the most famous productions of his little press at Passy concerned the Indians. The first, a famous hoax, was an alleged account of the barbarities of the Indians in the employ of the British army. This was war propaganda, pure and simple, and so effectively and brilliantly conceived that Horace Walpole immediately identified Franklin as the author. The second was Franklin's delightful bagatelle, *Remarques sur la politesse des sauvages de l'Amerique Septentrionale.* It was less an analysis of the manners of the Indians than it was a subtle and gentle commentary on the civilized society that Franklin saw, understood, and loved, even though he recognized its artificialities and weaknesses. "Savages we call them," he began, "because their manners differ from ours, which we think the perfection of civility: they think the same of theirs. The Indian men, when young, are hunters and warriors; when old, counsellors; for all their government is by

counsel of the sages; there is no force, there are no prisons, no officers to compel obedience or inflict punishment." This, as Franklin well knew, was the sort of thing the romanticists of the Rousseau tradition wanted to hear. His remarks on the manners of the savages must be interpreted in that light. As such, the *Remarques* is superbly suited to its purpose; as a treatise on the Indians, it cannot bear comparison with such serious works as Cadwallader Colden's *History of the Five Nations* or James Adair's *History of the American Indians*. Franklin knew the Indians and they interested him, but he would not write a systematic treatise about them. He would not write about them at all, any more than he would about anything else, unless an immediate result was apparent: a result that might be a political end, a diplomatic strategy, or an amusing narrative, useful only for politeness' sake.

He proposed a plan for the union of the colonies and he found his materials in the great confederacy of the Iroquois. He championed the cause of the drunken Teedyuscung and the Delawares, not primarily because he thought they had been imposed upon, but because any instrument was good if it helped in the fight against Thomas Penn and the proprietors of Pennsylvania. In the realm of gallantry as in the political world he found the Indians useful: he told Madam Helvetius of the Indian custom of adoption to take the place of departed relatives and argued for his own adoption.

Yet, if Franklin used his knowledge of the Indians, as he used his knowledge of other things, to achieve immediate ends, it is not apparent that he misused the Indians. If we call him a friend of the Indians, we do so because he was a friend of all humanity. When we call the roll of great names associated with the American aborigines, we do not, at first, think of including his. He was no burning zealot, striving to convert the savage to the white man's way of life. He had no illusions about the red man any more than he had about his white brother. We do not think of him as we think of Eliot, Zinzindorf, Brainerd, Kirkland, Hawley, and the other great Indian missionaries. Franklin's first diplomatic effort was in the realm of forest diplomacy, yet we do not rank him with such a diplomatist as Conrad Weiser. He was an agent and emissary to the Indians, yet he does not compare in that

respect with Sir William Johnson. He wrote much about the Indians and he printed their treaties and the writings of others about the Indians. Yet we do not consider Franklin himself as a great source of Indian lore in the same manner that we consider Colden, Adair, or Weiser.

It will help to define Franklin's interest in the Indian if we consider also his interest in the Negro. These two races of non-Caucasian stock were about evenly matched in numbers in Pennsylvania in the eighteenth century. But the problems that they evoked and the attitudes toward these problems that they induced in the minds of the white race were enormously different. The Indian affected almost every phase of colonial life. He held the balance of power between the French and English and thus was the key to the whole question of international rivalry in America. He was not domesticated, but lived in his own villages beyond the frontier and thus impeded the natural flow of population westward. Every new immigrant who landed at Philadelphia was affected by this fact and in turn aggravated it, whether he knew it or not. The Indian supplied furs and peltry to traders, who exchanged them for London goods at such points as Philadelphia and Albany. Thus a whole commercial structure was erected with the Indian at the base—an Indian who, as Franklin told Lord Shelburne, knew nothing about credit and knew only how to respect an honorable obligation without the need for or an understanding of debtors' prisons. The Indian could wreck this commercial structure by the simple expedient of refusing to hunt. Thus he was an economic factor of the first importance, influencing and often determining the course of events from the wages of the counting-house clerk in Philadelphia to the decisions of the ministry in Whitehall. In the political realm the Indian was an ever-present problem, and one has only to read the journals of assemblies, the voluminous archives of governors and their councils, or the files of Indian treaties to see how potent a force he was in the politics of the colonies. More than one governor was ruined because he could not cope with the problem; more than one was made because he was astute enough to handle it. In the realm of political thought the Indian probably had a greater influence over civilized society than any other savage race. Marc

Lescarbot, Gabriel Sagard, and the authors of the great Jesuit Relations began in the 16th and 17th centuries by describing Indian society and ended by praising it with a praise which carried an implied criticism of the European political system. From this it was an easy step for Baron Lahontan to put in the mouth of an American savage a blunt criticism of civilized political organization. From these materials Montesquieu drew in part the inspiration for his *Spirit of Laws* and from the same sources emerged Rousseau's *Social Contract*. From Montesquieu and Rousseau to the French Revolution was but another link in the chain of influence that stretched from the western frontiers to the capitals of Europe, thus paralleling in political theory the links binding the American Indian to Europe in the economic world. The Indian, therefore, was a factor of immense importance in the 18th century, far out of proportion to his actual numbers.

The Negro on the other hand, while sharing similar racial handicaps, presented no baffling problems of power to the colonials. He was domesticated, serving in homes and on farms, and was not congregated in mass anywhere; indeed, there were laws to forbid it. His claims to social and civil rights were answered by simple denial. The one problem presented by the Negro was the problem of slavery, which was attacked, when it became urgent, on moral and economic grounds. It did not become an urgent problem until the 19th century.

Here, then, were the two minority elements in the population which presented actual and potential problems. The first was so complex and of such magnitude that it can be fully understood only when we compare it with some great social problem of our own day, such as the problem of capital and labor. The Indian was such a question in the eighteenth century, demanding of the merchant, the politician, the scholar, the clergyman, the frontiersman, and the soldier constant search for an adequate answer. The Negro made no such insistent demands by his presence, even when he outnumbered the Indian. His appeal was only to the humanitarian instincts of the Age of Enlightenment.

Such an appeal was met, in the case of Franklin, by active

intercession. Franklin was among the first to point out the economic disadvantages of slavery. He suggested the first school for Negroes in Philadelphia. He was president of the first abolition society in America. Among his last public acts, three concerned slavery. One was an *Address to the Public* issued in November, 1789; another was a memorial to the first Congress on the subject; and the third, published in the *Federal Gazette* within a month of his death, was a hoax and a parody ridiculing the debate in Congress on this memorial. With respect to the Negro, Franklin leaned in the direction of the social reformer, lending his name and his influence to such ardent leaders of the movement as Clarkson, Benezet, and Brissot de Warville. The Society of Friends were mobilized then, and have been ever since, to aid the Indian and to improve his status. But Franklin's name, so conspicuous in the history of abolition of Negro slavery in eighteenth-century Pennsylvania, is not to be found among those who promoted the Friendly Association and other ventures designed to help the Indian.

We would make a mistake to assume that because of this Franklin was less interested in the Indian than he was in the Negro. He was fully aware of the tremendous importance of the Indian. He knew that the answer of the frontiersman to the Indian problem, that of extermination, was dangerous, unwise, and unjust. He knew that the merchant and the Indian trader too often exploited the Indian for the sake of profit and played upon his weakness for strong drink. He knew that the demands of the missionaries that the Indian give up his traditional ideas of government, morality, and religion were essentially futile. He knew that the answer of the scholar—the answer of thinkers like Lahontan and Rousseau looking at Indian society from a distance of three thousand miles—had little of reality in it. Franklin realized the need for practical political adjustments to solve the multiform problems raised by the Indian. His humanitarian instincts carried him only so far as to stand against injustice to him. In the final analysis, the difference between Franklin's attitude toward the Negro and his attitude toward the Indian was not humanitarian in origin but intellectual. The Negro was transplanted and needed support and encouragement.

The Indian was on his native soil and had developed his own civilization. Franklin had a wholesome respect for any civilization that could produce noble specimens of intellect and sagacity. Hence his solution of the problem was simple: the American forest was ample and apparently inexhaustible—let the Indian inhabit it, continue in his own way of life, and be protected against injustice by means of established boundaries and protective legislation. In his own day, this may have been an adequate solution; certainly it was realistic. The fallacy in it was that the forest was not inexhaustible.

If respect for the Indian was the measure of Franklin's attitude, it was also the surest basis for a friendly and just treatment. Franklin, who understood people so well, knew a statesman when he saw one, whether he lived in Versailles or belonged to the Iroquois Long House. In 1747 he received the first copy of Colden's *History of the Five Nations* in the London edition of that year. He must have read with approval Colden's appraisal of the Iroquois. "The Five Nations," Colden wrote, "are a poor Barbarous People, under the darkest Ignorance, and yet a bright and noble genius shines through these black clouds. None of the greatest Roman Heroes have discovered a greater love to their Country, or a greater Contempt of Death than these Barbarians have done, when Life and Liberty came in Competition: Indeed, I think our Indians have outdone the Romans in this particular; for some of the greatest Romans have Murder'd themselves to avoid shame or Torments, Whereas our Indians have refused to Die meanly with the least pain when they thought their Country's Honour would be at stake by it, but gave their Bodies willingly up to the most cruel Torments of their Enemies, to show, that the Five Nations consisted of Men whose Courage and Resolution could not be shaken." Colden may also have told Franklin the story of Consora, the famous sachem of the Senecas, who spoke for them at all treaties. In 1721 Consora, described by Colden as "a very cunning suttle Fellow," told the Five Nations that they should join neither the French nor the English "but to keep the balance betwixt the two, for if the English should prevail over the French the Five Nations would . . . enslave themselves [to the English] . . . But if

[they] would now observe an exact Neutrality they would be courted and feared by both sides." Consora, like other Iroquois statesmen before and after him, followed this policy invariably and exacted concessions for his neutrality time after time. But when he was unable to restrain the warlike habits of his followers he put himself at their head and called out: "I did not dissuade you out of fear, but for your own good and since you will go to war, I shall be the first to lead you to slavery and destruction."

It is unthinkable that Franklin would establish schools or attempt to reform a way of life that produced such astute manipulators of statecraft as Consora. It is not certain that Franklin ever met the great Onondaga leader who was one of the successors of Consora, but I should like to imagine that he did. Canasatego, one of the most intelligent of all the Iroquois leaders, and perhaps the most eloquent, witnessed his greatest triumph of diplomacy at the Lancaster treaty of 1744, attended by representatives of Virginia, Maryland, and Pennsylvania. Whether Franklin ever met Canasatego or not, he has immortalized him in one of his famous Passy bagatelles. But the story that Franklin told in his *Remarks Concerning the Savages* is not comparable to the Onondaga orator's own arguments and negotiations as set forth in the account of the treaty of Lancaster which Franklin printed in 1744.

Perhaps in the printing of this treaty, and the thirteen other stately folios like it, Franklin performed his greatest act of friendship for the Indians. For in them are to be found the eloquent words, often wise and profound, of the best of their leaders. In them are to be found the exact rituals of the forest people in their formal conferences and contracts with their conquerors. In them are to be found metaphors and images of the forest, poetic clothing for the harsh realities of land deals and trade in the ephemeral trinkets for which a proud and imperious people sold their birthright because the sale was forced. In them are to be found the evidences of genuine statecraft on the part of such intelligent leaders as Shikellamy, astute and aloof, Canasatego, logical and crafty as well as eloquent, Teedyuscung, drunken and bombastic, but courageous and daring enough to lead his people to a

temporary independence. Franklin did not attend the conference at Lancaster in 1744, but if he read the minutes of the negotiations, in which Canasatego proved more than a match for the embassies from Maryland and Virginia combined, he must have agreed with Richard Peters, who wrote of that picturesque conclave: "I make no doubt that the Indian treaty will give everyone pleasure that reads it and as the Indians really appear superior to the Commissioners in point of sense and argument, it will raise peoples opinions of the Wisdom of the Six Nations and give the government at home higher notions of their consequence than they could have before." When Peters, who was present at the treaty, spoke of the superior sense and argument of the Indians, he really was speaking of Canasatego, who made all of the speeches for the Iroquois and who was the dominant figure at Lancaster.

In our effort to see the Indians as Franklin and his contemporaries saw them, let us picture Canasatego and his counsellors at Lancaster. It was a colorful assembly. Hundreds of Indians in full panoply, men, women and children—grave leaders, savage-looking warriors; Conrad Weiser, the skilful diplomat; Governor George Thomas of Pennsylvania, presiding over the sessions with a warm friendship and full respect for the powers of Canasatego; the Virginia and Maryland Commissioners, described by Richard Peters as "seven fine flaming gentlemen"; members of the Society of Friends come to see justice done to the Indians; finally the great Onondaga, Canasatego, "a tall well-made man" with "a very full chest and brawny limbs . . . a manly countenance . . . with a good natured smile. He was about sixty years of age, very active, strong, and had a surprising liveliness in his speech." Day after day the ritual of replenishing the Council Fire, of smoothing the road between the two peoples, of brightening the chain of friendship occupied the attention of all those present. Then Canasatego made his demands, demands in the form of ultimata. Maryland cited deeds a century old to the lands claimed by Canasatego. Canasatego replied that a hundred years meant nothing to a people as ancient as the Iroquois. In the end he won, single-handed, and, laden with goods and gold, clothed in a scarlet camblet

coat and a fine gold-laced hat, he marched his people off to Canada to sell his pledge of neutrality to the Governor of Canada for the highest price his astute diplomacy could achieve.

To think of Franklin trying to domesticate a leader such as Canastego, to establish schools to mold him and his followers in the white man's image, to teach him the arts and sciences of civilized society, to make him conform to its government, its laws, and its political theories, is impossible. It would have been like attempting to make a domestic fowl out of a proud and imperious eagle. Franklin understood humanity better than to make the attempt. He would assist in doing it for the Negro, because the Negro was differently situated; but, in Franklin's day at least, the Indian was untameable.

The Canasatego episode that Franklin recounts in his Passy bagatelle emphasises this. It was said to have occurred at the Lancaster Treaty, though there is no account of it in the official minutes of that conference. It seems that the Virginia commissioners offered to take six Indian boys and educate them at the College of William and Mary. Canasatego, deferring his answer out of politeness until the next day, declined the proposal. Some of their young men, he said, had gone to college in the northern provinces and had come back "bad runners, ignorant of every means of living in the woods, unable to bear either cold or hunger, knew neither how to build a cabin, take a deer, or kill an enemy, spoke our language imperfectly, were therefore neither fit for warriors, hunters, nor counsellors; they were totally good for nothing." But, subtle and cunning as well as polite, betraying also the proud belief he held in the validity of his own way of life, Canasatego turned to the commissioners with a counter-proposal that was two-edged. To show the Indians' grateful sense of the Virginians' offer, he said, he and his counsellors desired to make this offer: "If the Gentlemen of Virginia will send us a Dozen of their Sons, we will take great care of their Education, instruct them in all we know, and make *Men* of them."

The story, as Franklin knew, would delight the romanticists of the Rousseau tradition. It was the sort of anecdote that made him appear to all France as the apotheosis of the

natural man, the forerunner of the Golden Age of simplicity and of institutions grounded on nature's law. But for us it is also a story that illuminates Franklin's attitude toward the Indians. If Franklin never met Canasatego, he would have liked him and he would have respected a diplomat who could parry a stroke in such a fashion. It was, in fact, a Franklinian feat.

Franklin, then, respected the Indians and was content to let them live their own life. But he was also wise enough to profit from the things that he learned of them. One of America's great contributions to the history of political thought has been its working out the problem of federation. Franklin, as all the world knows, erected one of the mileposts in the development of the theory of federation in America when he met the commissioners of the various colonies at the famous Albany Congress of 1754. What he proposed there came in part from the Iroquois. Again we must go back to the wise Canasatego. At Lancaster in 1744 and at Albany in 1745, he admonished the jealous, bickering colonists to be united, and pointed again to the Indian example as a wise precedent to follow. "Our Wise forefathers," he said "established Union and Amity between the Five Nations. This has made us formidable. This has given us great weight and authority with our neighboring Nations. We are a powerful confederacy, and by your observing the same methods, our Wise Forefathers have taken, you will acquire such strength and power. Therefore whatever befals you, never fall out with one another." Though he did not realize it, Canasatego was advising one of the first steps in the long story of the American Revolution.

Franklin plainly had the Confederation in mind when he drew up his Plan of Union to be presented at the Albany Congress. He well knew that strength came through union, that the Iroquois confederation of 15,000 persons wielded an influence all out of proportion to their numbers; that its empire held sway from the St. Lawrence to the James, and from the Hudson nearly to the Mississippi; that conquered tribes paid tribute to the Iroquois, who alone could say who should make war and who should dictate the terms of peace. Here indeed was an example worthy of copying. "It would

be a strange thing," wrote Franklin, "if Six Nations of ignorant savages should be capable of forming a scheme for such an union and be able to execute it in such a manner that it has subsisted ages and appears indissoluble, and yet that a like union should be impracticable for ten or a dozen English colonies, to whom it is more necessary and must be more advantageous, and who cannot be supposed to want an equal understanding of their interest." I do not mean to imply, as some students would have it, that the principle of federation, indeed that the roots of the federal constitution, go back to the Iroquois Confederacy. The idea is much older than that. Franklin merely pointed to an obvious American precedent, already in existence and working effectively.

Franklin's first argument for Union was not thrown off, as his *Autobiography* has it, on his way to Albany. It appeared in the form of a letter to James Parker, the printer of a pamphlet by Archibald Kennedy on *The Importance of Gaining and Preserving the Friendship of the Indians to the British Interest, Considered.* This pamphlet was published in 1751, at a period when Thomas Penn, Richard Peters, and others were advocating a union of the colonies to solve the common problem of the Indian. Indeed, less than a month before Franklin wrote his observations on Kennedy's pamphlet in the form of a letter to Parker, Thomas Penn wrote to Peters: "I think it would be of the greatest advantage to the English interest for several colonies to join in the management of Indian Affairs and appoint, as you suggest, deputies from each of them to manage the whole, agreeing upon a proportion that each colony will bear of the expense." This was the germ of the idea contained in Franklin's *Concise Hints on a Plan of Union* of 1754. *Concise Hints* contained, among its most important proposals, provision for a governor general and a grand council to be made up of representatives of the colonies. The very first power that Franklin would have granted to this central government was the authority to negotiate all Indian treaties in which the general interest or welfare of the colonies was concerned; to make peace or war with the Indians: to make laws regulating Indian trade; and to have exclusive control over all purchases of Indian lands. This was a logical outcome of the sentiments expressed in

his letter to Parker in 1751, commenting on Kennedy's manuscript. "I have read the Manuscript you sent me," he wrote Parker, "and am of Opinion with the Public Spirited Author, that securing the Friendship of the Indians is of the greatest Consequence to these Colonies; and that the surest means of doing it are to regulate the Indian Trade, so as to convince them by experience, that they may have the best and cheapest Goods, and the fairest Dealings from the English; and to unite the several Governments so as to form a strength that the Indians may depend upon for protection in case of a rupture with the French; or apprehend great danger from, if they should break with us." When Franklin thus approved Kennedy's proposal for a union of the colonies and for a unified Indian policy based on decent treatment of the Indian as a neighbor in peace and an ally in war, he concluded with a modest note: "I wish I could offer any Thing for the Improvement of the Author's Piece, but I have little Knowledge and less Experience in these Matters." Almost half a century later he declared that if the colonies or the ministry had accepted the Plan of 1754, which both rejected because each feared it allowed too much power to the other, the American Revolution would never have occurred when it did or perhaps for another century.

Too late—and too ineffectual when it came—was the crystallization of the need felt by all for united counsels. Dissensions between governors and assemblies, intercolonial jealousies, and trade rivalries were too strong to be overcome by the efforts of men like Franklin, Kennedy, Colden, Penn, Peters, and others to secure some sort of colonial union. The Albany Plan of Union, wrote Governor Thomas from Antigua, "smells strong of Pennsylvania." Pennsylvania had indeed had a leading hand in the events of the three years leading up to the Albany Congress, and Franklin was its architect, but it was not accepted by the colonies and was never submitted to Parliament. The treaty with the Indians at which the Plan was drawn up only served to drive another wedge between Pennsylvania and the western Indians, to drive deeper the wedge between Pennsylvania and the Iroquois. On his way home from Albany, Franklin wrote his old friend Colden: "After all nothing of much importance was transacted

with [the Indians]: At least nothing equal to the extent and trouble of so many colonies." For once Franklin, so intent on the crying need for the solution of the problem, seemed to be unaware of the fact that the Albany Treaty constituted one of the most glaring examples in colonial history of the dangerous if not unfair manipulation of Indian affairs by colonies with conflicting interests. As one of the commissioners from Pennsylvania, it was his official duty to do what his Plan of Union forbade: to hold private councils with the Indians, over their protests, and to purchase from the Iroquois almost all of the lands of Northwestern Pennsylvania. A few days later the Commissioners of Connecticut, in an even more secretive manner, induced some of the same chiefs to sell some of the same lands to Connecticut. Thus as Franklin was pressing his *Concise Hints* for a unified and just plan of dealing with the great common problem of the Indian, he was officially a partner to the evils that he hoped to correct. The blow that united counsels might have warded off fell in full strength on the defenceless frontiers of Pennsylvania the next year.

When that blow fell, Franklin wasted no effort in useless argument over what might have been. His habitual approach in all fields of endeavour was to do the thing at hand that needed to be done. He had counselled for just and united dealings with the Indians. That had failed. The Indians were now murdering defenceless settlers, burning their houses and barns, slaughtering their animals, and carrying away their wives and daughters. The problem now was one of fighting. Franklin proved that, though a good friend to the Indians, he could also be a good enemy. In the early summer he secured almost single-handedly the wagons that were essential to the progress of Braddock's ill-fated army. In September, as Speaker of the Assembly, he was no doubt present at the State House to see and hear one of the most dramatic spectacles that ever took place in that historic building. Scarouady, the Oneida chieftain, who had served with Braddock and had lost a son, gave the Pennsylvania government a final opportunity to support the western Indians against the French. Demanding that he be heard by the principal men of the colony, he was granted the privilege of speaking

in the State House before the governor, the Assembly, and a large audience of civilians. In a sense he was announcing the declaration of independence of the Delawares, and he came not as a supplicant but as a proud warrior. He demanded in the name of the Indians he represented that Pennsylvania declare whether she intended to be an ally or an enemy. To the Assembly he said: "We do, therefore, once more invite and request you to act like men, and be no longer women, pursuing weak measures, that render your names despicable." To the governor he said: "One word of yours will bring the Delawares to join you." That word was not given. For the governor and the Assembly were already at loggerheads over the taxation of the proprietary estates, a fight which Franklin had helped to precipitate and which would carry him to London a year and a half later. But when the angry frontiersmen threatened to march on Philadelphia and when they dumped a wagonload of scalped corpses on the steps of the State House to show the Assembly and the governor what their idle bickering over prerogative had produced, an appropriation of £60,000 was promptly made for defense. A month later, in December, 1755, Colonel Benjamin Franklin, at the head of a military command, marched on the frontier and assumed charge of the erection of blockhouses for defense. Franklin was as open an enemy as he was a friend of the Indians.

Whether he was planning measures to win the friendship of the Indians, as at Albany, or whether he was leading an expedition against them, he always had concise hints to throw out. This time it was to suggest a new method of fighting. Franklin had shown in his letter to James Parker in 1751 that he too knew something about Indian fighting. "Every Indian is a Hunter," he had said, "and as their manner of making War, *viz.*, by Skulking, Surprizing and Killing particular persons and families is just the same as their manner of Hunting, only changing the object, Every Indian is a Disciplin'd Soldier. Soldiers of this kind are always wanted in the colonies in an Indian War, for the European Military Discipline is of little Use in these Woods." Now, lacking enough soldiers of the Indian type, Franklin proposed that Indians be hunted down with dogs. "If dogs are carried out with any

party," he wrote to James Reed and Conrad Weiser, "they should be large strong and fierce and every dog lead in a slip-string to prevent their tiring themselves by running and discovering the party by barking at squirrels, etc. Only when the party come near thick woods and suspicious places they should turn out a dog or two to search them. In case of meeting a party of the enemy the dogs are all then to be turned loose and set on. They will be fresher and finer for having been previously confined and will confound the enemy a good deal and be very serviceable. This was the Spanish method of guarding their marches." Apparently the suggestion was not acted upon at the time but it is interesting to note that no less a military authority than Colonel Bouquet proposed to Sir Jeffery Amherst the same expedient in fighting Indians. Franklin's keen interest in making things more effective was never-failing, whether it was a problem of ventilation, of correcting a smoking chimney, of navigating the Gulf Stream, or of making better friends with or better war against the Indians.

In 1756 Franklin had his second experience of forest diplomacy. He had been one of the principal commissioners at the Carlisle Treaty of 1753 and in 1775 he would again be called upon to negotiate for the united colonies with the western tribes. But his service as a commissioner at the Easton Treaty of 1756 had more important consequences than any of his other experiences as an Indian diplomat. For there he saw Teedyuscung, the leader of the Delawares against whom he had led his expedition in 1755, and he heard the fiery chieftain demand compensation from the Penns for the lands that he claimed his people had been defrauded of in the famous Indian Walking Purchase twenty years before. He witnessed also the dramatic ritual by which the Six Nations conceded the independence of the Delawares and acknowledged openly that Teedyuscung had thrown off the mantle of womanhood that the Iroquois had placed on his people and had achieved, if not the full stature of manhood, at least the right to make war and peace as men. Of all the vexations that Thomas Penn had endured as proprietor of the province, none stung him so deeply as this charge that he had made use of fraud in the purchase of lands. He had bought the

same lands over and over from the Indians and he had made a sincere effort to continue the wise and humane policies of his father in this respect. Franklin knew this and had said so in the *Pennsylvania Gazette* as long ago as 1736. He knew also that there were many forces back of Teedyuscung's charge that would make it appear less as an original thought on the part of the Indian leader than as an insinuation on the part of those desiring to embarrass the proprietors politically. Eventually even Teedyuscung admitted that this was true. But now Franklin was engaged in a struggle with the proprietary system, and any grievance, real or imaginary, was ammunition for his armory. When he went to London to represent the Assembly, he personally presented the grievances of the Delawares to the ministry. His friendship for the Indians was now bound up with the popular movement against the Penns—a movement which Richard Peters, not without cause, described as "Mr. Franklin's Declaration of War against the Proprietaries." "The [Indians'] complaints are now in the hands of the Ministry," Franklin wrote Galloway in 1758, "but when they will have leisure to consider them, God only knows. For tho' securing the affections of the Indians by doing them justice, be a matter of great consequence, they have other affairs at present on their hands that seem to them of more immediate importance."

About this time the manuscript of Charles Thomson's "Enquiry into the Causes of the Alienation of the Delawares and Shawanese" came into Franklin's possession. This was a strongly partisan statement, growing out of the activities of the Quaker Friendly Association. But its indictment of the Penns, in a strange mixture of humanitarianism and political expediency, immediately appealed to Franklin as a means of arraying public and official opinion against the proprietors. Accordingly he assumed charge of the manuscript, edited it, and procured its publication. He informed Galloway in 1758 that "It is more read than I expected. It will, I think, have a good effect." The almost apoplectic rage that filled Thomas Penn when he read it is revealed in the many marginal notes that he scribbled in the copy that now reposes in the John Carter Brown Library. The effect on the ministry is apparent from the peremptory order issued to

Sir William Johnson to hear the complaints of the Delawares and to see that justice was done. This was bitter medicine for Thomas Penn, but he accepted it manfully and made full peace with the Delawares. Franklin, though moved perhaps more by political considerations than by altruistic motives, could be a friend of the Indians even when there was grave doubt of their deserving it. He had fought against Teedyuscung's people in the forests of America. He was now fighting for them at Whitehall, fighting all the more effectively because he and Teedyuscung had a common foe in Thomas Penn.

If Franklin's motive in this fight was identified with a popular movement with which he sympathized, he nevertheless showed that he could stand courageously for justice to the Indian even when such a stand called for opposition to popular clamor. In one of the few examples of Franklin's opposing the people, he acted as he did because he was outraged by the behavior of his fellow men. This stand he took in the year that the Indians really needed friendship, the year 1763 which brought to an end the ancient rivalry with France in the struggle for North America and also brought to an end the power that the Indians had long held and for which they had been courted and treated with respect. The so-called Conspiracy of Pontiac brought the horrors of Indian warfare again to the province of Pennsylvania. The long-suffering frontiersmen, seeing no good in an Indian except in a dead one, threatened to march on Philadelphia to inflict punishment on the friendly Moravian Indians interned there, and the Paxton Boys fell on the peaceful Conestoga Indians at Lancaster, killing old men, women, and children with a brutality scarcely matched by anything the Indians had done. This famous massacre set off a tempest of political and religious controversy in the province, and while Franklin was fully aware of whatever extenuating circumstances there may have been, he boldly proclaimed the act of the Paxton Boys to be what it was—cold-blooded murder. This forthright comment made more enemies than friends for him, but he did not spare the murderers. Branding the Paxton Boys as "Christian White Savages," he said: "There are some (I am ashamed to hear it), who would extenuate the enormous wickedness of these

actions by saying: 'The inhabitants of the frontiers are exasperated with the murder of their relations by the enemy Indians in the present war.' It is possible. But though this might justify their going out into the woods, to seek for those enemies and avenge upon them those murders, it can never justify their turning into the heart of the country to murder their friends. . . . The only crime of these poor wretches seems to have been that they had a reddish-brown 'skin and black hair; and some people of that sort, it seems had murdered some of our relations. If it be right to kill men for such a reason, then, should any man with a freckled face and red hair kill a wife or child of mine, it would be right for me to revenge it by killing all the freckled face and red hair men, women and children I could afterwards anywhere meet with." Citing instances of hospitality among the ancient Greeks, Turks and Saracens, Franklin concluded that the peaceful Conestoga Indians "would have been safe in any part of the known world except in the neighborhood of the Christian White Savages of Peckstang and Donegall." When the frontier mobs finally moved on the city, determined to exterminate the Moravian Indians and to browbeat the Assembly into granting measures of defense against the Indians, it was to Franklin, the author of this philippic against brutal murder, that the governor turned for assistance. The insurgents halted at Germantown and Franklin with three other men went out to reason with the leaders in behalf of law and order. He was successful in dissuading the insurgents. "Within four-and-twenty hours," he wrote Dr. Fothergill, "your old friend was a common soldier, a councillor, a kind of dictator, an ambassador to a country mob, and, on his returning home, nobody again."

Two central facts emerge from an examination of Franklin's long experience with the American Indian: his natural respect for them and his desire to see no injustice come to them. At the end of his great career he wrote: "During the course of a long life in which I have made observations of public affairs, it has appeared to me that almost every war between the Indians and whites has been occasioned by some injustice of the latter towards the former. It is indeed

extremely imprudent in us to quarrel with them for their lands, as they are generally willing to sell, and sell such good bargains: And a war with them is so mischievous to us, in unsettling frequently a great part of our Frontier, and reducing the Inhabitants to poverty and Distress, and is besides so expensive that it is much cheaper as well as honester, to buy their Lands than to take them by Force." In this homely advice to the governor of Georgia, as well as in his counsel to Lord Shelburne on the Indian problem, Franklin viewed the subject dispassionately and open-mindedly, his clear intellect going at once to the heart of the issue and offering the simplest of solutions. His wise solutions were not always adopted. His genuine respect for the Indians and his stout advocacy of justice and fair-dealing were not always shared. Franklin must have realized, as he witnessed the Indians' decline to a pitiful remnant of their former power, that this was one of the inevitable results of the establishment of a nation to which his own genius had contributed so much.

TRANSMISSION OF POWER IN COMPRESSED GAS ATMOSPHERES.

BY

HENRY M. HOBART,

10 Balltown Road, Schenectady, New York.

(Continued from September issue.)

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Temperature Considerations: As to the particular gas to be employed, our LIBRARY RESEARCH indicates that nitrogen is inferior to CO_2 in several important respects. It may be objected that since the critical temperature of CO_2 is 31° C., trouble will be encountered due to condensation when lower temperatures occur, since we are proposing to use a compression of some 50 ata. This objection may be met by

arranging in any one of several simple ways, that the temperature of the gas inside the pipe always shall be maintained at a reasonable margin above 31° C., say, around 36° C. For a 60-cycle transmission line, a particularly appropriate procedure will be to thermostatically control the degree of phase compensation. Our conductor, within its enclosing pipe, is characterized by having rather high capacitance, notwithstanding that gases have unity dielectric constant. In order to keep down to a reasonable amount, the leading component of the current in the conductor, various ways of providing for an increase in the inductive loading may be employed. Some of these ways readily adapt themselves to permitting automatic adjustments of the inductive component of the current in the conductor, and hence also of the I^2R loss per unit length of the conductor. In this way, we can automatically control the temperature of the CO_2 (or other gas) within the pipe, without changing the amount of power (i.e., the "in-phase"), component of the load on the system.

Capacity-current Compensation: At p. 10 of the January, 1934 issue of the (British) *Journal of the I. E. E.*, in discussing underground paper cables, Mr. P. V. Hunter makes the following comments regarding capacitance compensation:

> "It seems probable that the resultant cable will require some measure of compensation for capacity current, when operating with alternating voltages of 132 kV. and higher. This has been investigated in a preliminary way, and it appears that the most convenient method is to increase the magnetizing current of the step-down transformers, as this is cheaper than to provide special reactance equipment."

From a note dealing with the subject of "Cable-Capacitance Compensation" at p. 259 of the July, 1941 issue of the (British) *Journal of the I. E. E.*, Part I, the following quotation is of interest:

> "On the Paris 220-kV. system, the step-up transformers are fitted with a tertiary delta 11-kV. winding to which one or more shunt reactors may be connected at will by switchgear. The generators and transformer primary windings may thus operate at nearly unity power factor."

In present-day underground paper-cable practice, we have to severely restrict the cable's operating temperature in order to preserve the good condition of the paper insulating material, and thus lengthen the cable's life. This necessary concern for the life of the cable, often requires the provision of much larger and much more expensive cables than otherwise would be needed. But in the compressed-gas alternative, so far as regards any concern over deterioration of materials, we are free to permit any desired operating temperature.

Constant-temperature Operation Eliminates Need for Expansion Joints: There is a further important consequence of automatically maintaining a constant temperature in the compressed gas inside the pipe, for all loads and all external temperatures, irrespective of whether the pipe-line is located underground or near or at the surface. This relates to the elimination of the need for embodying features, such as expansion joints, for taking care of expansion and contraction of the pipe. If, for providing greater accessibility, a location right at the surface is desirable, or on posts providing a height of a few feet above the surface, the greater variations in the surrounding temperature (as compared with a buried cable), no longer will constitute an obstacle.

There are other gases of higher dielectric strength than CO_2, which can be used at high compression, provided we maintain the temperature above the condensation point corresponding to that pressure. Notable examples are SO_2 and CCl_4. It is not known to the writer that much in the way of test results regarding the 60-cycle dielectric strengths of these gases at very high compressions, has been published. Figure 5 presents curves of the dielectric strengths, in crest volts per mil, corresponding to moderately uniform fields and a 500-mil spacing, for several gases for compressions up to some 60 ata. There is included the lower portion of an SO_2 curve. Throughout the small range of pressures for that curve (i.e., up to 20 ata), its dielectric strength is seen to be much greater than the dielectric strengths of air, CO_2 and nitrogen. When completely free from even the slightest trace of H_2O, the SO_2 gas exerts no deterioration on the materials which will be employed in the pipe-line transmission system or in the compressed-gas transformers which are a part of the system.

Comments on Carbon Tetrachloride: CCl_4 gas is reported to have even better insulating characteristics than SO_2, and should be useful in cases where its higher vaporization temperature for a given compression, can be suitably taken into account in the arrangements for automatic control of the gas temperature. The dielectric properties of CCl_4 gas may be found to be so much superior as to permit of obtaining desired results in some cases, when a substantially lower compression is employed than would be needed with other gases. CCl_4 gas at a compression of 20 ata, probably will have a dielectric strength equal to that of CO_2 at 50 ata. It is well known that, even in its liquid form, carbon tetrachloride is an excellent insulation, although, in liquid form, it has proved insufficiently inert for some applications. As a compressed gas, however, it is quite probable that with appropriate design and choice of materials, it can be successfully employed in transformers, since there are now available, various insulating materials (such as flexible glass tapes and sheets, asbestos, mica, mycalex, and other inorganic materials), which reasonably can be expected to withstand any corrosive action of CCl_4 gas, even at quite a high temperature.

In a paper entitled: "D.C. Breakdown Strength of Air and Freon in a Uniform Field at High Pressures," pp. 132 to 135 of Vol. 60 (1941), of *A. I. E. E. Transactions*, Trump, Safford and Cloud attribute the greater insulation strength of "certain compounds in the gaseous state, notably those which contain chlorine, fluorine or other negative atoms," primarily to two causes: (1) "the relatively large number of inelastic impacts which an electron may make in such gases with consequent loss of energy and ionizing power," and (2) "the electron affinity of the electro-negative particles in the gas, such as the chlorine and fluorine atoms." The authors state this to result in "the removal of free electrons from the gas with the accompanying formation of relatively inert negative ions."

At p. 511 of the March 15, 1937 (Vol. 51) issue of the *Physical Review*, in an article entitled: "Effect of CCl_4 Vapor on the Dielectric Strength of Air," Rodine and Herb make the following observation:

> "It may be of interest to note that . . . certain results indicated that CCl_4 vapor may be more efficient

for suppression of corona discharge than for suppression of sparking."

The Impulse Strength of Compressed Gases: In an earlier section of this article, allusion was made to an important advantage of the pipe-enclosed construction, namely that it protects the high-voltage conductors from lightning. But if the pipe-enclosed part of the system is only employed as a branch or extension of an existing OVERHEAD line, this COMPLETE immunity from lightning surges, evidently is not provided. But even in those cases, there is the advantage that the amplitude of a lightning impulse entering the pipe-line, will be effectively attenuated as the impulse travels along the conductor, and, for usual conditions, it will become innocuous after traversing a very few thousand feet of the pipe-line. The rate and amount of the attenuation obviously depends upon the conditions of each case.

However, the general proposition of using compressed gas as insulation, continues to be criticized from the standpoint of those who still consider that compression may not increase the impulse strength of a gas to so great an extent as it increases the 60-cycle strength.

Only as recently as a very few years ago, it was quite widely believed by transformer specialists, and also by some underground-cable specialists, that: "INCREASE IN GAS PRESSURE HAS NO EFFECT ON ITS IMPULSE STRENGTH." Serious consideration of the use of compressed gases as insulation, was delayed several years by the persistence of this tradition. Gradually that claim has become greatly modified. It is now usually conceded that in fairly uniform fields (such as the gap between large-diameter spherical electrodes with not-too-great spacing), the impulse strength increases with increasing compression, and to the same extent as does the 60-cycle strength. Under those conditions, the IMPULSE RATIO of a gas is unity (the impulse ratio being defined as the ratio of the crest value of the voltage of a so-called $1\frac{1}{2}$, 40 impulse wave, which can be withstood for three micro-seconds, to the crest value of the 60-cycle sinusoidal voltage which can be withstood for one minute). A $1\frac{1}{2}$, 40 impulse wave is defined

as a wave with a "front" so steep as to travel past a given reference mark in 1.5 micro-second and having a "tail" requiring 40 micro-seconds to decrease in amplitude to one-half of its crest value. With rod-gaps (which represent a fairly extreme case of a non-uniform field), the test results for the impulse breakdown voltage, sometimes are quite erratic, particularly for large spacings.

The obvious lesson is that all reasonable efforts should be made to provide for as uniform fields as practicable, either by using appropriate surface shapes in the designs, and smooth surfaces, or by so interposing barriers of solid insulating materials as to tend to decrease stress concentrations. Experience doubtless will teach us additional means for achieving the desired degree of field uniformity.

In an interesting and valuable paper by Mr. G. C. Nonken, entitled: "High-pressure Gas as a Dielectric," presented on Oct. 8, 1941, at an A. I. E. E. session, particular attention was given to impulse voltage phenomena with sphere-gaps and with rod-gaps, and for a wide range of spacings. The impulse employed was the standard $1\frac{1}{2}$, 40 micro-second wave. For rod-gap spacings greater than 800 mils, the results, in the writer's opinion, provide no satisfactory clues to the fundamental principles involved. For some compressions (when associated with spacings greater than 800 mils), the strength for a given rod-gap spacing, was greatest with 60-cycle stresses, while for other compressions but the same spacings, the breakdown strength was greatest with impulse stresses. Both for impulse and 60-cycle stresses (in the case of rod-gaps with spacings greater than 800 mils), increased compression (for a given spacing), in some cases, increased, and in other cases, decreased, the breakdown voltage. Mr. Nonken's paper dealt with two gases, nitrogen and freon. In the rod-gap tests, these two gases behaved very differently from one another, not only for the 60-cycle stresses, but also for the $1\frac{1}{2}$, 40 micro-second impulse stresses.

800-mil-spacing Breakdown Curves: Concentrating on the spacing of 800 mils, which, from the data in the Nonken paper, appears to be the limit up to which, with rod-gaps, his curves

are relatively free from caprices, the curves in Fig. 6, have been prepared. The freon and nitrogen curves are designated respectively by the letters *F* and *N*. The curves re-

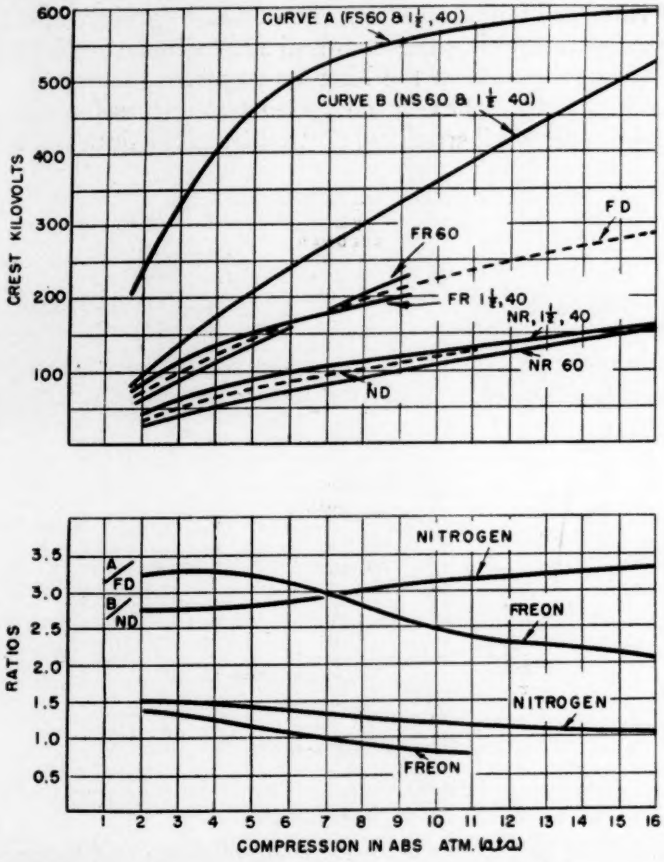

FIG. 6. Curves for freon and nitrogen (F & N) with sphere-gaps and rod-gaps (S & R) and with 60-cycle and impulse stresses (60 & 1½, 40); the spacing being 800 mils for all cases.

lating to sphere-gaps and rod-gaps are distinguished by the letters *S* and *R*. Tests in the gap between two 6¼ cm. diameter spheres were regarded as corresponding to moder-

ately-uniform field distributions. But for the 800-mil spacing, there was, of course, a slightly greater departure from uniform-field conditions than with the 400-mil spacing. This is indicated by the slightly lower breakdown strengths (expressed in crest volts per mil), found for the 800-mil spacing, and may be seen by comparing the 800- and 400-mil curves plotted in Fig. 7 from the data in the Nonken paper.

In Fig. 7, there have been added two curves for nitrogen for 40-mil and 2-mil spacings, plotted from the data published

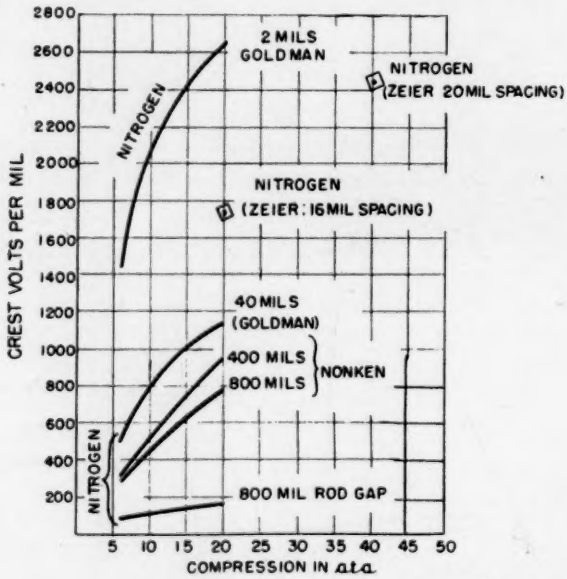

FIG. 7. Dielectric strength of nitrogen for various spacings and compressions.

by Goldman in a paper entitled: "Breakdown of Compressed Nitrogen in Small Gaps" (*Comptes Rendus, Doklady, de l'Academie des Sciences de l'U.R.S.S.*, 1938, Vol. XVIII, No. 2), The results of two tests by Zeier are also plotted in Fig. 7. From Goldman's 2-mil and 40-mil curves, and Nonken's 400- and 800-mil curves, the following table has been prepared. For nitrogen at various compressions up to 18 ata, the table shows the measured 50- and 60-cycle breakdown strengths in crest volts per mil:

TABLE OF BREAKDOWN STRENGTHS OF COMPRESSED NITROGEN FOR 50- AND 60-CYCLE STRESSES.

Compression in ata.	Crest, Volts per Mil.			
	2-mil Spacing.	40-mil Spacing.	400-mil Spacing.	800-mil Spacing.
6	1500	500	337	300
8	1870	640	425	375
10	2100	770	525	450
12	2280	860	620	525
14	2400	950	705	590
16	2500	1000	790	655
18	2570	1050	880	720

In the above table, the dielectric strengths for the 2-mil spacing, are seen to be from (1500/300 =) 5.0 to (2570/720 =) 3.6 times greater than with the 400-times-larger spacing of 800-mils. It is important to note that, for nitrogen, the above data indicate that the trend is for this ratio to decrease with increasing compression, and it might be expected to be considerably smaller at 50 ata, i.e., the higher the compression, the less may be the susceptibility of nitrogen to a decrease in its breakdown strength with increasing non-uniformity of field for the case of sphere-gap and plane-gap tests.

For nitrogen, there is plotted in Fig. 8 (for a compression of 20 ata), a curve with the 50- and 60-cycle stresses, in crest volts per mil, as ordinates, and the spacings (in mils) as abscissæ. It is seen that for spacings which are only moderately different from each other (say 2 to 1), the percentage change in dielectric strength is (except for extremely small spacings), only a matter of a few per cent., whereas in the case of fields of much greater non-uniformity, the percentage change (as a function of the spacing), would be considerably greater. [NOTE: For the sake of completeness, it should here be stated that for the 40-mil and 2-mil gaps, Goldman used a steel sphere of 20 mm. diameter, opposite the center of a flat disc of 50 mm. diameter.]

Going back to the curves in Fig. 6, for all of which the spacing is 800 mils, the letters *S* and *R* are employed to designate the sphere-gap tests and the rod-gap tests. The rod-gap electrodes were $\frac{1}{2}''$-square, brass rods. This con-

struction of gap is regarded as typical of a decidedly non-uniform field.

60 cycle breakdown tests were made both with the sphere-gap (S) and with the rod-gap (R), as also 3 microsecond breakdown tests with a $1\frac{1}{2}$, 40 impulse wave. The 60-cycle tests are designated by *60*, and the impulse tests by $1\frac{1}{2}$, *40*. For the sphere-gap, the breakdown voltage, for all compressions, is the same with 60 cycles as with the standard $1\frac{1}{2}$, 40 impulse wave; i.e., the IMPULSE RATIO is unity.

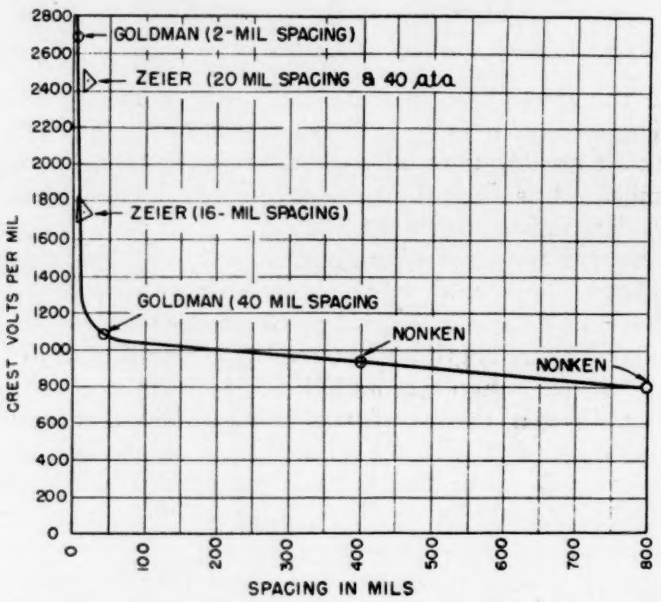

FIG. 8. Goldman-Nonken-Zeier curve for dielectric strength of nitrogen at 20 ata and various spacings. (Note one additional point for 40 ata.)

As an illustration of the plan of designation employed in the Fig. 6 curves, the one marked "*NS 60 & $1\frac{1}{2}$, 40*," shows for nitrogen (N) and for compressions up to 16 ata, the sphere-gap breakdown voltages for 60 cycles (60) and also for the $1\frac{1}{2}$, 40 impulse wave (& $1\frac{1}{2}$, 40). The tests for that curve were made with the sphere-gap (S), and the spacing was 800 mils.

But for the rod-gap (for the spacing of 800 mils used for all the curves in Fig. 6), the two kinds of stress (60 cycle and

impulse) result in different values of the breakdown voltage. The differences are, however, so relatively small that there have been drawn two dotted lines, *FD* ("freon dotted") and *ND* ("nitrogen dotted"), which can be considered as ROUGHLY representative of the rod-gap breakdown voltages for freon and nitrogen respectively, irrespective of whether the stresses were 60 cycle or impulse.

The IMPULSE RATIOS for nitrogen and freon for rod-gaps, are shown in the two lowest curves in Fig. 6. The impulse ratio for the sphere-gap, for gases at all compressions, is unity, provided that the diameters are sufficiently large relatively to the spacing.

The curves *A/FD* for freon, and *B/ND* for nitrogen, probably are innovations. It is believed that they provide an important criterion of the suitability of the gases as dielectrics at high compressions and high voltages, even when the available facilities do not permit of obtaining direct tests at more than rather low compressions and relatively low voltages. Thus if we examine the *A/FD* curve, we shall see that for freon, the dielectric strength in a rather non-uniform field, increases from about three-tenths of the sphere-gap strength at the low pressure of only 2 ata, up to five-tenths when the pressure is increased to 16 ata, and that the shape of the curve indicates a continuance of the increase with further increase in the compression. This result for FREON agrees with the trend observed for NITROGEN in the sphere-gap and "sphere-plane" tests on which is based the table on p. 339.

The OPPOSITE trend is seen to be indicated with the *B/ND* curve representing NITROGEN, the ratios of rod-gap to sphere-gap strengths being respectively 0.33 and 0.29 for compressions of 2 ata and 16 ata. The curves thus indicate NITROGEN to be much more unfavorably affected by increased non-uniformity of the field than is FREON, and the shape of the *B/ND* curve indicates that the inferiority of NITROGEN in this respect will be even more pronounced at compressions higher than those shown in Fig. 6. This increasing inferiority of NITROGEN in non-uniform fields as the degree of compression is increased, is precisely the opposite to the trend deduced from the values in the table on p. 339 which related

to sphere-gap and sphere-plane tests. The inconsistency should be investigated by means of further tests.

Although their methods of approach were quite different, Zeier and Finkelmann previously have reported adversely as to the merits of NITROGEN in the matter of its suitability as an insulator when highly compressed. Provided the trend observed for FREON of better retaining its dielectric strength in non-uniform fields the higher the compression, is confirmed by further investigations, then the outlook would appear especially favorable also for SO_2 and CCl_4, because of the fact that they share in some respects, the physical and chemical properties of FREON.

There are wide dissimilarities in different gases with respect to their dielectric characteristics and propensities. Since these simple comparisons of only two gases (selected by chance because the data were conveniently accessible in the Nonken paper), lead so readily to important clues (even although they are sometimes conflicting), it is reasonable to expect that other simple comparisons of the results of tests with other gases and under a great variety of conditions, gradually will lead us to evidences of further trends by which to select much more suitable gases or mixtures of gases, than is possible with our present far-too-slight understanding of the subject. It is the writer's belief that we already know enough for careful applications to useful purposes, but the applications will be crude as compared with those which will follow when more researches have been undertaken and more of these trends have been corroborated or contradicted.

At p. 208 of the 2nd, edition of Arnold Roth's fine treatise entitled "Hochspannungstechnik" (Springer. Vienna, 1938), Roth states:

> "The IMPULSE RATIO is very dependent upon the electrode SHAPE. It is high with points and low with plates and spheres. The sphere gap can therefore be used for measuring the crest value of impulse waves, provided its spacing is not chosen too great with respect to the sphere diameter."

In addition to the effect on the impulse ratio, of the physical design of the gap, we now learn, from the two lowest

curves in Fig. 6, that the impulse ratio for an 800-mil spacing, varies considerably with the degree of compression, and also is different with different gases.

Time and Money-saving Expedients for Making Dielectric Tests of Compressed Gases: It is unfortunate that most of the published data of this subject of the dielectric characteristics of compressed gases, relate to only very moderate compressions. The cost of the tests increases rapidly with increased compression, increased spacings, and increased breakdown voltages. The curves in Fig. 6, with the evidence which they afford of fairly definite relations and trends between the dielectric strength with rod-gaps and sphere-gaps respectively, suggest a way of decreasing these testing costs, and the testing difficulties, and thus obtaining much more quickly the data we so much need, particularly as regards such dielectrically very strong gases as sulphur dioxide, sulphur hexafluoride, dichlorodifluoromethane and carbon tetrachloride.

If the tests are made with rod-gaps, the breakdown voltages will be so very much lower for these dielectrically very strong gases, that even with great compressions and great spacings, the size and cost of the required pressure tanks and bushings and electrode fittings will be so much smaller, simpler, and less expensive, and the testing difficulties and precautions will be so greatly decreased, as to considerably advance our prospects of obtaining with less delay, a helpful amount of additional knowledge.

With the additional information revealed by such ratio curves as those in Fig. 6 (A/FD for freon and B/ND for nitrogen), we shall, in due course, learn by what factors to multiply the rod-gap breakdown voltages in order to deduce (admittedly roughly), the values of the breakdown voltages which would have been observed if the tests had been made with sphere-gaps with diameters adequately greater than the spacings being investigated.

Compressed Gas for Power Transformers: In some quarters, it has been felt that the need for employing higher-than-usual temperatures in order that CO_2, SO_2, and CCl_4 shall not condense at the degree of compression needed for high insulation strength, is a requirement which generally will disqualify

them from use at high pressures for insulating and circulating purposes. The writer disagrees with this conclusion, and believes that on the contrary, the requirement to provide the corresponding high temperature, often may be associated with advantages of importance.

Thus, in the case of a compressed-gas transformer, the stream of ascending gas will be heated by the losses as it passes over the winding surfaces and ducts. Condensing conditions will be provided in an appropriate portion of the transformer tank, or in a special compartment into which the hot gas will pass on its arrival at the top of the transformer tank. Then the dielectric will descend by gravity in its completely or partly condensed condition, and will be again heated and vaporized in the middle or lower portions of the tank where the active material of the transformer is located. Obviously, a fan or blower may be employed to circulate the dielectric at higher speeds in the interests of the desired thermal design, and possibly also to increase the dielectric strength by increasing the mobility of the gas for the degree of compression employed.

The MacLaren Effect: Long ago, it was pointed out by MacLaren (Vols. XXX and XXXI, 1911 and 1912, of the *A. I. E. E. Transactions*), that if a transformer core composed of laminations prepared with suitable physical treatment, and of suitable chemical composition, is operated at an appropriately-high temperature, its hysteresis loss will be greatly reduced.

In recent discussions of this subject, transformer specialists have asserted that the decrease in hysteresis loss due to the MACLAREN EFFECT, will, at the flux density employed, be accompanied by such a decrease in permeability, and corresponding increase in the required magnetizing component of the transformer current, as to cancel any advantages as regards decreased core loss in the transformer. This, however, does not prove to be the case if the appropriate kind of core material is used. Tests to decide this point, were specially made on one of the very best brands of low-loss transformer iron. These tests showed that the increases in the magnetizing current at the desired high temperature, were of only such moderate amount as not to be of any con-

sequence with respect to the very advantageous use of the MACLAREN EFFECT in transformer design. Since, however, transformer oil of reasonable cost gradually deteriorates by sludging unless the temperature is kept down to a very moderate value, and since, until recently, appropriate insulating materials which withstand high temperatures for long periods, had not been developed in forms in which they could be used effectively in transformers, the MACLAREN EFFECT could not be used to any advantage in OIL-TYPE power transformers. With the increase in our knowledge of how to use compressed gas successfully as insulation and as a circulating medium, together with the present availability of turn and layer insulations of flexible-glass-tapes and sheets, spacers and supports and barriers of porcelain, glass, asbestos, mica, micalex and other heat-resisting materials, there ceases to be any good reason for not resorting to the high-temperature operation of transformers when sufficient advantages will accrue therefrom. There will also be the usual great gains accompanying the decreased size and weight and cost associated with the proper employment of high temperature in the design of electrical machinery. With appropriate designing, the efficiency will not be impaired by the fact of the use of high temperature.

"Thermal-screen" Transformers: One arrangement for the employment, in transformer construction, of these thermal principles in combination with compressed-gas circulation, consists in interposing a "thermal screen" between the core and the windings. A considerable portion of the heat from the core will escape by flowing outward across the thickness (say $\frac{3}{8}''$ or so), of the thermal barrier, and thence will be carried away mixed with the lower-temperature heat from the windings.

Due to the use of the thermal barrier, the windings may be operated at a very much lower temperature than that maintained in the core. Nevertheless the winding temperature-rise (by resistance), may, in appropriate cases, amount to 140° C., or even more. With a typical ambient temperature of 30° C., this corresponds to a winding temperature (by resistance), of 170° C., or over.

The greater part of the gas stream will pass up through

the windings outside of the thermal barrier, and will rise in temperature up toward, say, some 30° C. less than the temperature of the windings, as determined from resistance measurements.

Making Practical Use of Vaporization and Condensation of the Circulating Gas: Freed from the temperature limitations imposed by oil immersion, several desirable but heretofore inapplicable features can be embodied in power transformers.

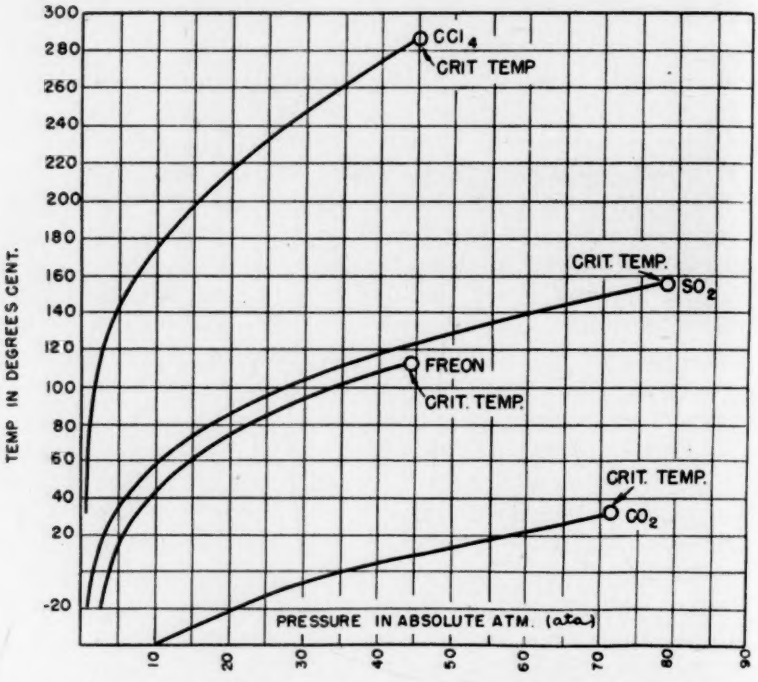

FIG. 9. Temperature-pressure vaporization curves of four gases.

Some of these relate to the utilization of vaporization and condensation. In other words, we may employ our dielectric for a part of the time in the gaseous, and part of the time in the liquid form. It will be seen from the SO_2 curve in Fig. 9, that in order that SO_2 shall retain the gaseous form at a compression of 50 ata, its temperature must exceed 130° C. A margin of some 10° C. probably is desirable in order to

avoid the liability of having any liquid mist held in suspension in the gas stream. Thus its temperature should be increased to about 140° C.

From Fig. 5, it is seen that SO_2 gas, at a compression of 50 ata, has a much higher dielectric strength than air or CO_2 at that compression.

We may so design the circulation, that part of the gas stream shall pass over the windings outside of the thermal barrier, at a mean temperature of some 140° C. On emerging into the spaces above the windings, it will be joined by, and will mix with, a stream of SO_2 gas which has attained a far higher temperature in traversing passages adjacent to the hot core, but a portion of which has had its temperature greatly reduced in escaping across the thermal barrier (with a thickness of a quarter of an inch or more) into passages between the outside of the barrier and the inside surfaces of the winding. Let us assume that the average temperature of the stream of gas after traversing the barrier, is well above 200° C., and that the mixture formed by the joining of the two streams has an average temperature of, say, 180° C., and that the resultant stream enters the condensing dome, indicated diagrammatically at *D* in Fig. 10, at that temperature.

In view of the great amount by which the temperature of the stream of gas when it enters the condensing dome (180° C.), exceeds the temperature of the water in the tank surrounding the dome (100° C.), it follows that it will require only a moderate total surface area of properly-proportioned, finned, heat-transfer surface and associated piping, to vaporize the water within the tank, at the rate necessary to wholly or partly condense the SO_2 gas entering the condensing dome.

Evacuator: It may be desired to further decrease the temperature of the boiling water in the tank (*W*, in Fig. 10), so as to have a greater difference of temperature between the compressed gas in the dome (*D*), and the water in the tank (*W*). The greater this difference in temperature, the smaller need be the total heat-transfer surface which will be required. For accomplishing this purpose, we may employ a blower designed for the high speed and high operating temperature used successfully in super-chargers. This EVACUATOR will throw or suck out through suitably shaped and located apertures, the

steam above the water surface, at such a volumetric rate as to reduce the pressure on the water surface, and will consequently also reduce the vaporization temperature. The power consumed by this auxiliary will slightly decrease the total efficiency of the transformer installation, but the simplicity of the method sometimes will make it preferable to resorting to a condenser, when a vaporization temperature lower than 100° C. (say 90° C.), is desired.

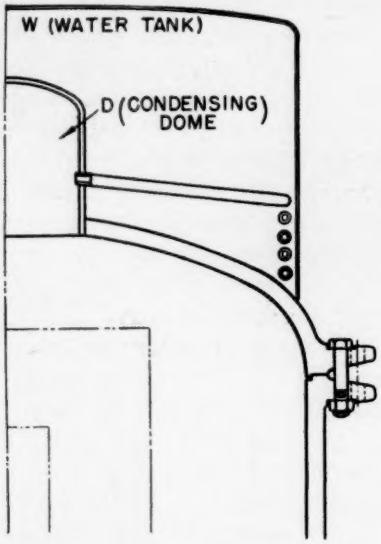

FIG. 10. Diagrammatic sketch relating to a compressed-gas power transformer employing water-vaporization to remove the heat due to the losses.

The cooled dielectric will descend by gravity through suitable passages leading to the lower portion of the transformer tank. It will enter this lower portion at a temperature of (for example) 125° C. The dielectric next may pass over hot-copper base-plates, which are in intimate thermally-conducting relation with the bottom part of the very hot transformer core, from which a stream of heat flows to, and is absorbed by, the dielectric. As the result of this heat transfer, the dielectric is vaporized, and raised to a temperature suit-

ably in excess of 130° C., ready for the next cycle of heat-transfer events.

Power Required for Compressed-gas Circulation: It requires almost negligible power to circulate the stream of compressed gas at very high speeds (such as a matter of 500 to 1000 feet per minute). In certain designs laid out for study purposes, the gas-stream circulation for a 12,500 kVA compressed-gas power transformer, was estimated to require only about 5 hp. (0.04 of 1 per cent. of the rated output of the transformer). Interest attaches to knowing the losses and efficiency estimated for this study-design for a 12,500 kVA compressed-gas power transformer. They are as follows:

Copper loss at rated load	46.0 kW
Core loss (not taking into account any decrease by MacLaren Effect)	21.5 kW
Stray loss plus ventilating power	7.5 kW
Total loss at rated load	75.0 kW
Efficiency at rated load and unity power factor:	99.4%

Power-transformer Cooling by Water Vaporization: Let us now make a rough quantitative examination of the economics of vaporization and water cooling for a 12,500 kVA power transformer by the plan of condensing the compressed gas in a dome at the top of the transformer, and vaporizing the water in a tank surrounding the condensing dome, as illustrated diagrammatically in Fig. 10. The amount of water required to be evaporated annually, is so small that it may be allowed to go to waste, passing off from the tank as steam at atmospheric pressure. It will be replaced at a rate governed by automatic control of the water level in the tank. The transformer's rated load loss is 75 kW. The latent heat of the steam is 286 w. hr. per pound, and the make-up water comes to 760 U. S. gallons per 24-hr. day. At a cost of 7 cents per 1000 gallons, this comes to a total cost of twenty dollars per year for make-up water. Even in places where the cost of water is much greater, it will not amount to a sum of any consequence, since the value of the ANNUAL output of the transformer is several hundred thousand dollars.

Probable Consequences to Power-transformer Design, of Release from the Limitations Imposed by the Use of Oil: It is

evident that the preliminary suggestions which have been given in this article, concerning new procedures in power-transformer design, which will become practicable with the release from the limitations associated with the use of oil, simply are indicative, and doubtless not in all respects nor in every instance, the best for accomplishing the desired objects. Very many alternatives will be devised to take advantage of these groups of new factors, and many minds will work independently in devising "better ways."

There is little or no originality in these vaporization-cooling methods. However, their effectiveness for use in transformers is greatly increased when oil's low temperature limit is removed. Vaporization-cooling principles may be worked out in many different ways, but a very serious impediment to their use in transformers, was the low service temperature necessary when oil was employed for circulation and insulation.

Locating the Transformer Underground: The elimination of (1) high-voltage bushings (often having heights of over 15 feet above the top of the transformer tank), and (2) the absence of the fire risk associated with the use of transformer oil of usual cost, combine to permit compressed-gas power transformers to be installed inside of substation buildings. An UNDERGROUND location also becomes attractive. Aside from the short, low-voltage bushings, nothing need emerge from the transformer tank except a steel pipe of a few inches diameter. This steel pipe contains compressed gas and extends from the transformer tank to the transmission pipe-line. The latter should, at any rate for the portion at or within the sub-station building, be located a few feet above the floor level.

A typical transformer substation will contain 8 transformers (4 step-down and four step-up, 2 of the 8 being spares), or multiples of these numbers. All switch-gear, such as dis-connectors and the low-voltage circuit-breakers, will be installed in metal enclosures. For structural reasons, the transformer's tank should be of rather small diameter and great total height, often 12 to 20 feet or more. Of this total height, all but a few feet should be sunk in a vertical, cylindrical pit, below the floor level. The few feet of the tank

which project above the floor level will have a much thicker steel wall than the 12 to 20 feet occupying the cylindrical pit. The protruding upper end provides for convenience of installing and for subsequent accessibility. The tank is to be regarded as a permanent compartment. The design will permit of the removal, servicing, or replacement of the actual transformer.

A tank installed in this way, may be made of thinner metal than otherwise would be required, since it will derive from the opposing pressure of the surrounding pit wall, great mechanical support to resist the internal gas pressure. The space between the internal wall of the pit, and the external surface of the tank, will be filled with a strong mass of suitable material to supplement the strength of the steel wall of the tank. This filling material will be of such composition and will be so applied as to exert a great and evenly-distributed compression on the entire outer surface of the tank.

In a compressed gas, 60-cycle, 165,000 volt, 12,500 kVA transformer, this underground location, with the thinner tank wall, reduces by some 5 tons, the amount of steel required for the tank wall. As compared with an OIL-type transformer for the same rating, there is eliminated the need for several thousand gallons of transformer oil. These savings in STEEL and OIL should be particularly welcome at the present time, because of the NATION'S urgent need of these two materials for the defense program. Another large item of economy as compared with the OIL equivalent, is effected by eliminating the expensive, and in other respects undesirable, high-voltage entrance bushing. It is evident that these savings, together with the considerable savings effected by being able to operate the transformer at temperatures which could not be permitted with the OIL type, certainly will greatly decrease the compressed-gas transformer's cost much below the cost of an oil transformer for the same rated output and voltage.

Further Consideration of Particular Features of the Pipe-enclosed, Compressed-gas, 60-Cycle, Transmission System: Our attention must now again be turned back to the transmission line. Although the step-down and step-up compressed-gas transformers are constituent parts of the transmission system, there is no need for employing the same gas or the same degree

of compression in the one as in the other. Stop-joints will serve to separate them, and will also permit of sub-dividing the long-distance transmission line into any suitable number of short sections. The subject of effective stop-joints for a compressed-gas system such as we are considering, has been carefully studied, but it will not be taken up in this already very long article, further than to state that the associated technical problems are much simpler than the corresponding technical problems encountered with solid-insulated, high-voltage underground cables.

In this transmission-line project, there usually will not be employed the same voltage throughout the entire length. The economics of each particular case will indicate very high voltages to be appropriate in traversing some districts (where, for example, infrequent outlets are required), and quite low voltages in other districts. Two such differing-voltage sections are in electrical communication with each other only through groups of step-down and step-up compressed-gas power-transformers whose low-voltage secondaries are interconnected through low-voltage circuit-breakers. By opening the circuit-breakers, the two sections are completely separated. The interposition of these transformer groups permits of employing circuit-breakers of much lower cost and greater dependability than are available for the currents and high voltages contemplated for (1) transmission systems, (2) interconnections, and (3) power pools, for great amounts of power.

Barrier Effect: The insulating and supporting design shown in Fig. 2, has the further advantage that the presence of the solid insulating barrier *D*, will serve considerably to increase the breakdown strength of the composite structure. Such barriers, properly located, serve to decrease stress concentrations in non-uniform fields, and it may reasonably be expected that the structure will have a considerably greater breakdown strength than without such an interposed barrier. The subject is, however, complicated, and there is but little experimental data for guidance. For systems employing still higher voltages, two or more properly-spaced, concentric barriers should be very effective.

If all three conductors are located in a single pipe, then the resultant of the currents in the three conductors is zero, and

the loss in the material of the pipe will be of small amount. Figure 11 illustrates diagrammatically, a model with three conductors in a single pipe. Interest attaches to the cranked type of insulating support there shown.

The National Defense: In view of the NATIONAL DEFENSE plans for expending half-a-billion dollars annually for increasing the NATION'S electricity-supply resources, it seems unfortunate that the system and apparatus which will be built on such an enormous scale, should be other than the most economical and appropriate available at the present time. The OIL transformers and the OVERHEAD lines of present standard practice, were evolved decades ago, for the relatively primitive conditions of those times. By the application of very great ingenuity on the part of many able engineers, to

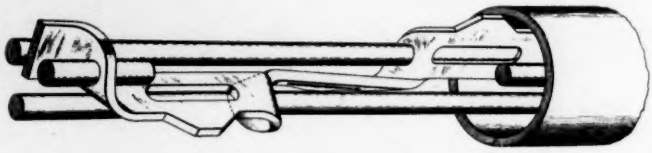

FIG. 11. Diagrammatic sketch of (1) enclosing pipe, (2) spacing insulator, and (3) 3 high-voltage 60-cycle transmission conductors for underground system for transmission of large amounts of power to great distances.

innumerable complicated details, these outgrown methods have been made to serve present requirements, but at a greater cost, and with various operating difficulties which are not encountered in the proposed system. At least, there should be made a thorough, serious, and sympathetic examination and study of all available sound alternatives.

Conclusion: Such a project as that described in this article, should, of course, be subjected to severe tests, and obviously it would be rejected if shown, by these tests, not to have the estimated features of great superiority over present methods. It should not be condemned without thorough investigation. If the advantages as to low capital cost and operating superiority should be demonstrated, then the system's wide use would be accompanied by savings running up to very large amounts.

If the NATIONAL EMERGENCY is successfully overcome much sooner than is expected, then, since this undertaking will be valuable as a permanent asset, its continued prosecution to complete development, will be an important component in the re-adjustment of the NATIONAL activities to normal conditions, or (as it has been aptly expressed) to help "cushion the jolt of shifting the nation's economy from preparedness to peace."

January 4, 1942.

ON A GENERALIZATION OF KIRCHHOFF'S THEORY OF TRANSVERSAL PLATE VIBRATIONS IN THE VIBRATION PROBLEM OF STEAM TURBINE DISKS.

BY

I. MALKIN,

Boston, Mass.

Introduction: a. The vibration problem in its actual aspects in the steam turbine design; *b.* The fundamental conception of the *solution used in the steam turbine practice* as derived from the Rayleigh Ritz method substituted for the original Kirchhoff theory; *c.* Illustration of the *actual problem* by an example taken from the one-dimensional theory of vibrations; *d.* The "Wheel Vibrations" of the disk; *e.* The blade vibrations with the disk proper entirely at rest; *f.* Asymptotical representation of the actual ("Disk Blade") vibrations of the disk; *g.* Simplifications used in the procedure of frequency computation; *h.* The disk with heavy rim.

a. The problem of axial vibrations of steam turbine disks has been treated very extensively in the technical literature.[1] The question of possible predetermination of the vibration frequencies in such disks was carefully investigated along two lines of attack, namely with the aid of an experimental method applied to the disk at rest as well as in running conditions, and by means of computation on the basis of Stodola's procedure developed from the well known minimum principle of Rayleigh (see this Introduction, *b*), which governs the fundamental vibration frequencies in elastic systems.

Numerous disks of various designs have been examined by both of the two procedures mentioned. The two sets of results obtained from those two methods were generally in agreement with each other except, however, in certain important special types of disks which did not obey the frequency laws as determined by the analytical method. These were the disks with long blades and those with heavy rims for two or more rows of blades.

[1] See f.i. W. Campbell, *Transactions of the Amer. Soc. of Mechan. Eng.* (in the following quoted as TASME), 1924, pp. 31–160, and W. Campbell and W. C. Heckman, ibid., 1925, pp. 643–671.

The research work was generally concluded on the basis of an experimental classification of great varieties of tested disks permitting the predetermination of the vibration frequencies with the aid of a kind of exhaustive disk catalogs. The discrepancies as such, between computation and experiment, were not removed.[2]

While the problem was thus solved from a point of view of immediate practical necessity in application to some sets of definite standard types of disks, the results obtained lose, of course, considerably in their value if they are to be applied to other sets of disks. It is, therefore, desirable to revise and to improve the analytical method so as to explain the discrepancies in question and to make it possible to determine the frequencies analytically in those cases as well, in which contradiction has been found between theory and experiment.

The present paper attempts to explain and to remove those contradictions and to indicate possible improvements of the procedure of frequency computation in the aforementioned special types of disks.

b. To find the source of the discrepancies, stated above, between computation and experiment, we shall start with a brief report on the development of the analytical method, upon which is based the technical procedure of frequency determination in steam turbine disks.

The solution of the fundamental problem of transversal plate vibrations has been given, in its essentially final form, by Gustav Kirchhoff.[3] The complete elucidation of the problem, characteristic of Kirchhoff's solution, has been obtained by a consequent application of the Hamiltonian Principle to the elastic problem of the plate. Kirchhoff's investigation treats, however, of the *solid plane* circular plate only and cannot be applied immediately to the problem of transversal vibrations of a turbine disk, because the latter is a plate of variable thickness and provided with blades at the rim.

[2] See *TASME*, 1924, pp. 82–90, esp. par. 140 and 142, and p. 157; also *TASME*, 1925, p. 668.

[3] G. Kirchhoff, "Vorles. ueber Mathem. Phys.," Vol. 1, *Mechanik*, Leipzig, 1897, p. 459; see also "Handbuch der Physik," Berlin, 1928, Vol. VI, p. 383, giving further information on the literature of the subject.

In order to make the advantages of a discussion by means of the Hamiltonian Principle [4] available for systems of more complicated geometrical shape, a treatment of more elementary mathematical character has been substituted for the "indirect methods" of the Calculus of Variations [5] with the ensuing system of differential equations, by means of which the Hamiltonian Principle of a continuum, say of an elastic body, primarily finds its mathematical expression and physical interpretation. Namely, the "direct method," introduced by W. Ritz,[6] although already earlier used, in a special form, by Lord Rayleigh,[7] reduces the variational problem to a comparatively simple problem of Maxima and Minima of functions.

So we arrive at the Rayleigh Ritz method which can be readily applied to the problem of transversal vibrations of the steam turbine disk.

This work has been originally attempted and successfully achieved, save for the exceptional cases mentioned above, by A. Stodola.[8] The fact that certain special varieties of disks do not comply with the numerical results of Stodola's procedure shows that the peculiar shape of those disks violates some restricting factors in the *original type* of the Hamiltonian variational problem of plate vibrations as we know it from Kirchhoff's theory, namely in the type from which Stodola derived his assumption concerning the *vibration form* of the disk, see the third paragraph in the following section *c* of this Introduction. This gap in the analytical treatment as adopted in the steam turbine practice and created by an unjustified extension of Stodola's procedure, is the subject of the immediately following consideration.

c. To give a preliminary illustration of the question, let us reduce the number of dimensions involved and consider first the simple (one-dimensional) case, represented in Fig. 1, of a bar with sudden change in cross section, clamped in at

[4, 5] See R. Courant and D. Hilbert, "Methoden der Mathem. Phys.," Vol. 1, Berlin, 1924, pp. 207 and 155 resp.

[6] Walter Ritz, "Oeuvres Complètes," Paris, 1911, pp. 192–250.

[7] Lord Rayleigh, "Theory of Sound," art. 182 of the first edition; see also F. H. van den Dungen, "Cours de Technique des Vibrations," Bruxelles, 1926, p. 44; furthermore A. Stodola, "Dampf- und Gas-Turbinen," Berlin, 1922, pp. 914–916 (section 187, e).

[8] A. Stodola, "Schweizerische Bauzeitung," 1914.

$x=0$ and forced to vibrate, by virtue of an instantaneous impulse, in the transversal (y-) direction. As in the case of a bar of constant cross section the vibration will be made up, at the beginning, of a certain combination of the lowest (fundamental) type and the higher types of transversal vibration, the combination being determined by the nature and location of the instantaneous impulse; after a short while the lowest type of vibration continues alone, exactly like in a bar of prismatic form. But in the case of a cantilever of discontinuous cross section shown in Fig. 1 the lowest type of transversal vibration is characterized by the fact that *only a section* AC of the heavier part OA is participating in the vibration of the part AB, if the length of the latter is large enough as compared with the length of the part OA.

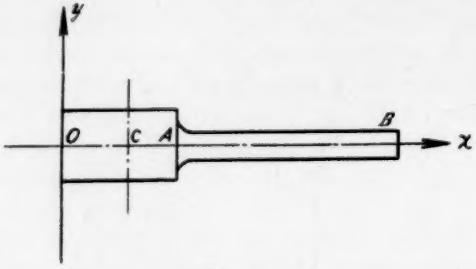

FIG. 1.

Quite a similar condition exists in a steam turbine disk with blades. If the blades do not exceed a certain length limit, the *entire* disk with the blades may be considered as participating in the vibration; but if the blades are long enough, the vibration phenomenon will occur mainly in the blades, and only an outer *ring part* of the disk will be involved in this vibration. We shall call "wheel vibrations" and "disk blade vibrations" the two kinds of vibration in question.

The fundamental conception of Kirchhoff's work on transversal plate vibrations is naturally characterized by a restriction to "wheel vibrations" alone, the subject of his investigation being a solid plane plate. This fundamental conception, taken over by Stodola, proved to be practically sufficient and satisfactory in the case of the steam turbine disk as well, if only the blade length, as compared with the

disk diameter, does not exceed a certain limit. In dealing with disks, in which this limit cannot be maintained, we have to free ourselves from the original pattern of Kirchhoff's variational problem, a complication which did not find due attention thus far.

More concretely, we have to conclude, in accordance with the above considerations and the example illustrated by Fig. 1, that in the case of a disk with blades of sufficient length the variational problem of the Hamiltonian Principle will require the additional work of determining a certain limiting circle, of radius r_1 (see Fig. 2 representing an idealized disk), sepa-

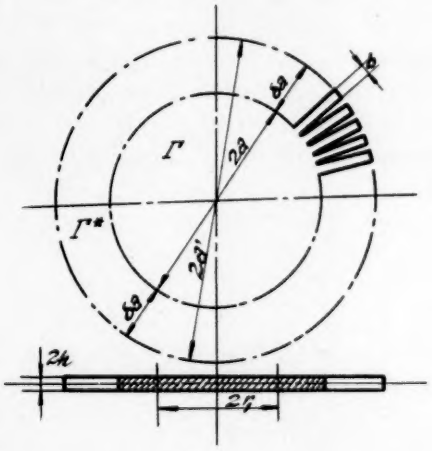

FIG. 2.

rating the *resting core* $0 \leq r \leq r_1$ from the vibrating part, this circle being of such a magnitude as to make the fundamental frequency of the transversal vibration of the disk with the blades as low as possible (the minimum value of the Hamiltonian Integral requires the minimum value of the frequency [9]). In other words, r_1 is an additional parameter of the new variational problem; this problem will be stated in its exact analytical form in section 2 ("indirect" method for the idealized disk), and also in section 8 ("direct" method for the actual disk).

[9] See f.i. A. Stodola, "Dampf- und Gas-Turbinen," section 187, e, mentioned above.

The solution of this variational problem is numerically, however, exceedingly tedious, as will be shown in the sections 2 and 8. We shall use, therefore, another procedure to arrive at practical conclusions concerning the actual vibration forms and frequencies (see *d*, *e*, *f*).

d. Following the historical course, which the problem has taken in the steam turbine practice, we shall *first* investigate the "wheel vibrations" of the turbine disk (in the idealized form represented by Fig. 2). As already pointed out above, the results, if used *immediately*, will be valid for disks with sufficiently short blades only. These results of the preliminary investigation in the sections 1 and 3, the first of which proceeds along lines suggested by Kirchhoff's aforementioned classical research, while the second is a frequency computation by means of the Rayleigh Ritz Stodola procedure, can be expressed briefly as follows.

The vibration form of the blade in the "wheel vibration" of the combined system is practically a straight line (as originally *assumed* in Stodola's computing procedure [10]) irrespectively of the blade length, provided, of course, we repeat it, that the "wheel vibration" is possible with blades of any length. The straight line form is proved in section 1 for vibrations with two nodal diameters and up to a blade length of about 0.3 of the wheel radius; but the result holds true for longer blades on the one hand and for more nodal diameters on the other, see section 3. So we may state that the "wheel vibrations" of the turbine disk are generally characterized by practically negligible bending energy of the blades, which have a vibration form coinciding almost entirely with a straight line. This result shows that the source of the aforementioned discrepancies between computation and experiment cannot have been in the unreliability of the straight line vibration form of the blade (in the "wheel vibration" of the combined system), as occasionally conjectured; [11] the critical point was rather, as already stated, in the conception, adopted in the technical computing procedure, that the combined system performs "wheel vibrations," in other words,

[10] A. Stodola, "Dampf- und Gas-Turbinen," art. 187, section a, 4.

[11] See *TASME*, 1925, p. 668.

that the *entire* wheel is participating in the vibration, no matter how long the blades may be.

Otherwise it should be noted that the analysis in section 3 checks that of section 1, and vice versa, entirely and completely, naturally, as far as only "wheel vibrations" are concerned.

e. The "wheel vibrations" just discussed can be obviously considered as a limiting case of the "disk blade vibrations," namely the limiting case characterized by the full participation of the wheel in the vibration. The other limiting case is represented by the transversal vibrations of a system consisting of an (absolutely) rigid disk with long elastic blades. In this *second* extreme case the transversal vibrations of the combined system are pure *blade vibrations* (the influence of the shrouds in the case of twisted blades is considered in section 9).

The procedure mentioned at the end of section *c* of this Introduction permits an approximate determination of the "disk blade vibrations," which are the actual vibrations of the disk, from the "wheel vibrations," as if they were possible with blades of any length, on the one hand, and the transversal vibrations of the blades alone, as if the disk proper were absolutely rigid, on the other. This approximate procedure is worked out in a numerical example (section 7), with respect to which it can be represented briefly as follows.

f. Considering a (conical) disk of some given dimensions we first calculate the "*wheel vibrations*" of the combined system with blades of varying length (sections 5 and 7, A). The frequencies thus computed are given graphically in Fig. 3 as a function (Ω_2, Ω_3, Ω_4, $\cdots$ for $k = 2, 3, 4, \cdots$ nodal diameters with no nodal circles) of the varying blade length. Then the lowest *vibration frequencies of the blade* are calculated under the assumption that the wheel does not participate at all in the vibration (sections 6 and 7, B). The curve of the fundamental frequencies of the blade alone is then plotted in Fig. 3 again as a function (Ω^*) of the varying blade length. Comparing the frequency curve of the "wheel vibrations" with that of the blade vibrations we find that, starting from a certain blade length, the frequency of the blade vibrating alone is lower than the frequency of the "wheel vibration" at

the same blade length. It follows then at once that the actual ("disk blade") vibration at this blade length will be of still lower frequency, because an outer ring part $r_1 \leq r \leq a$ of the wheel will join in the vibration of the blade in order to lower its frequency, in accordance with the minimum principle.

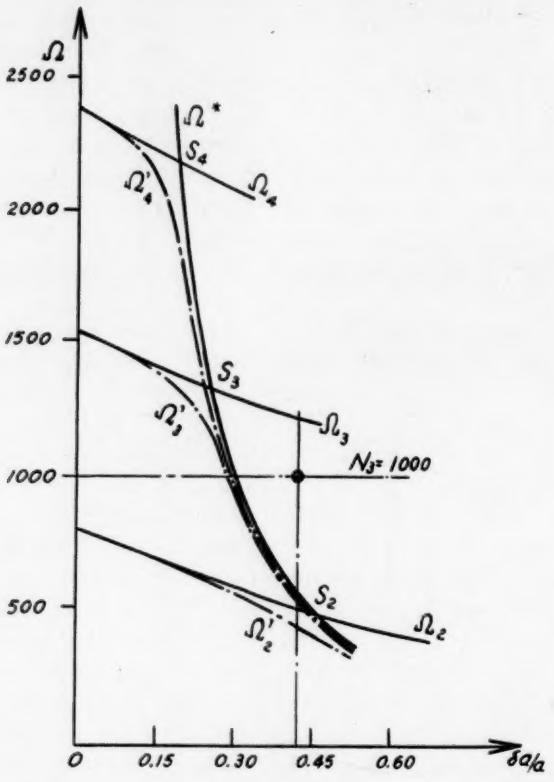

FIG. 3.

So we arrive at an estimation of the frequency curve of the "disk blade" vibration represented by the curves Ω_2', Ω_3', Ω_4', $\cdots$ in Fig. 3 (section 7, C). From this graphical representation we conclude, in particular, that starting from a certain blade length which is about $0.3a$ in the example treated in Fig. 3, the vibration frequency of the "disk blade" vibration is the same for all numbers $k \geq 3$ of nodal diameters.

Results of exactly this nature have been observed by experiment.[12]

g. The approximate method of frequency determination, and especially the estimation of the fundamental frequencies as outlined in section 7, is based upon certain simplifications in the complicated combined system consisting of disk, blades and shrouds. Such simplifications are necessary if the labor involved in the computation is not to exceed reasonable limits. The considerations, which tend to justify the simplifying assumptions, are given in section 9.

h. Coming finally to the disk with heavy rim, we are now able to indicate at once the source of the difficulties encountered in this particular problem,[13] starting from the points of view established in the above study of the disk with long blades. The cause of the discrepancies between analysis and experiment is again in the adoption of a vibration form, which is characteristic of a disk *free* at the outer boundary, like the plate in the original theory of Kirchhoff, while the disk with heavy rim approaches the case of a plate *clamped in* at the outer boundary. This produces a change in the vibration form. The corresponding modification of the problem is discussed in section 10 somewhat more in detail.

1. The "Wheel Vibrations" of the Idealized Disk Treated by an Extension of Kirchhoff's Theory of Transversal Plate Vibrations.—The following extension of Kirchhoff's theory of transversal plate vibrations to the case of the elastic system, represented in Fig. 2 (idealized disk), proceeds from the assumption that the transversal vibrations of this system are "wheel vibrations," see Introduction, *c*. The considerations laid down in the present section hold true, therefore, for the case only that the ring domain Γ^* in Fig. 2 is sufficiently narrow. The extension forms, however, the foundation for a more complete and more correct treatment at which we shall arrive by a certain modification of the analysis here offered.

The following system of equations (1)–(8), giving the analytical expression for the problem of the transversal "wheel vibrations" of the idealized disk, is obtained from the Hamiltonian Principle of the elastic problem as applied to

[12] See *TASME*, 1925, p. 660.

[13] See *TASME*, 1925, p. 668.

the system of Fig. 2 under the assumption of a resting core of vanishing diameter (see Introduction, *c*, semifinal paragraph; the *exact* form of the Hamiltonian Principle of the problem, valid for blades of *any* length, is given below in section 2). The deduction is, however, omitted here as the equations (1)–(8) represent but a simple generalization of the system of equations obtained in the original theory of Kirchhoff.

In using the designations E = Young's modulus of elasticity, ν = Poisson's ratio, ρ = mass density, n^* = number of the blades, $f = n^*b/2\pi a$ (see Fig. 2), t = time, ϑ = azimuth angle, Δ = plane Laplacian differential operator, as well as the designations given in Fig. 2, and with the indices r, t, and ϑ symbolizing differentiations with respect to the radius r, the time t and the azimuth ϑ we will have, for the transversal displacement W, resp. W^*, of the middle plane of the system represented in Fig. 2, in which the asterisk refers to the domain Γ^*, the differential equations

$$\frac{3(1-\nu^2)\rho}{Eh^2} W_{tt} + \Delta\Delta W = 0 \qquad \text{in } \Gamma, \tag{1}$$

$$\frac{3\rho}{Eh^2} W^*_{tt} + W^*_{rrrr} = 0 \qquad \text{in } \Gamma^*, \tag{2}$$

the "natural" boundary conditions

$$\left.\begin{aligned} &\nu\left(W_{rr} + \frac{1}{r}W_r + \frac{1}{r^2}W_{\vartheta\vartheta}\right) \\ &\quad + (1-\nu)W_{rr} - (1-\nu^2)fW^*_{rr} = 0 \end{aligned}\right\} \tag{3}$$

$$\left.\begin{aligned} &\frac{\partial}{\partial r}\left(W_{rr} + \frac{1}{r}W_r + \frac{1}{r^2}W_{\vartheta\vartheta}\right) \\ &\quad + \frac{1-\nu}{r^2}\frac{\partial^2}{\partial\vartheta^2}\left(W_r - \frac{W}{r}\right) \\ &\quad - (1-\nu^2)fW^*_{rrr} = 0 \end{aligned}\right\} \quad \text{when } r = a, \tag{4}$$

$$W^*_{rr} = 0 \qquad \text{when } r = a + \delta a, \tag{5}$$

$$W^*_{rrr} = 0 \qquad \text{when } r = a + \delta a \tag{6}$$

and the "enforced" boundary conditions

$$W = W^* \qquad \text{when } r = a, \tag{7}$$

$$W_r = W_r^* \qquad \text{when } r = a. \tag{8}$$

The general integral of (1) is well known from the original

theory of Kirchhoff and can be written in the form

$$W = \sum_k \sum_l W_{k,l}$$

$$W_{k,l} = (A_{k,l} \sin \alpha^2 \lambda_{k,l}^2 t + B_{k,l} \cos \alpha^2 \lambda_{k,l}^2 t) \sin (k\vartheta + \vartheta_{0k,l}) \times [I_k(\lambda_{k,l} r) + C_{k,l} I_k(i\lambda_{k,l} r)], \quad (9)$$

wherein k = number of nodal diameters, l = number of nodal circles,

$$\alpha^2 = h \sqrt{\frac{E}{3\rho(1 - \nu^2)}}, \quad (10)$$

$\alpha^2 \lambda_{k,l}^2$ = frequency of the natural vibration with k nodal diameters and l nodal circles, $i^2 = -1$, I_k = Bessel function of the first kind and the order k, while $A_{k,l}$, $B_{k,l}$, $C_{k,l}$ and $\vartheta_{0k,l}$ are arbitrary constants.

The general integral of (2) is, as well known again from the theory of bar vibrations,

$$W_{k,l}^* = [P_{k,l} \sin \alpha^{*2} \lambda_{k,l}^{*2} t + Q_{k,l} \cos \alpha^{*2} \lambda_{k,l}^{*2} t] \times [a_{k,l} \sin \lambda_{k,l}^* r^* + b_{k,l} \cos \lambda_{k,l}^* r^* + c_{k,l} \sinh \lambda_{k,l}^* r^* + d_{k,l} \cosh \lambda_{k,l}^* r^*], \quad (11)$$

wherein $r^* = r - a$; the coefficients of the first of the two bracketed expressions are independent of t and r^*, but they may be functions of ϑ; the coefficients of the second bracketed expression are constants; and

$$\alpha^{*2} = \sqrt{\frac{E}{\rho} \frac{h^2}{3}} = \sqrt{\frac{E}{\rho} \frac{J^*}{Q^*}} \quad (12)$$

(J^* = moment of inertia involved and Q^* = cross section area of the blade).

Substituting now the particular integrals (9) and (11) into the boundary conditions (3) and (4) we first find at once that a vibration of the combined system is only possible if

$$P_{k,l} = A_{k,l} \sin (k\vartheta + \vartheta_{0k,l}); \quad Q_{k,l} = B_{k,l} \sin (k\vartheta + \vartheta_{0k,l}); \quad \alpha^{*2} \lambda_{k,l}^{*2} = \alpha^2 \lambda_{k,l}^2, \quad (13)$$

in other words, the combined system vibrates as one unit.[14]

The third of the equations (13) leads with (10) and (12) to

$$\lambda_{k,l}^* = \frac{1}{\sqrt[4]{1 - \nu^2}} \lambda_{k,l}.$$

[14] Cf. W. Campbell, l.c., pp. 47–51.

Introducing the equations (13) into (11) we now see that in fulfilling the boundary conditions (3)–(8) only the expressions in the last brackets in (9) and (11) are to be taken into consideration. Substituting those bracketed expressions into the four boundary conditions (5)–(8) and in using the designations

$$\left.\begin{array}{c} \lambda\delta a\colon (1-\nu^2)^{1/4}=\mu; \qquad M=1+\cosh\mu\cos\mu; \\ M_1=\sinh\mu\cos\mu; \qquad M_2=\sinh\mu\sin\mu; \\ M_3=\cosh\mu\sin\mu, \end{array}\right\} \tag{14}$$

in which the indices k, l are suppressed in the quantities λ, μ, M, M_1, M_2, M_3 to simplify the formulas, the solution of the system of the four equations mentioned yields the following expressions for the coefficients occurring in the second brackets in (11):

$$\left.\begin{array}{l} 2Ma_{k,l}=(M_1+M_3)S(a)+(M+M_2)S'(a) \\ 2Mb_{k,l}=(M-M_2)S(a)+(M_1-M_3)S'(a) \\ 2Mc_{k,l}=-(M_1+M_3)S(a)+(M-M_2)S'(a) \\ 2Md_{k,l}=(M+M_2)S(a)-(M_1-M_3)S'(a), \end{array}\right\} \tag{15}$$

wherein

$$S(a)=I_k(\lambda_{k,l}a)+C_{k,l}I_k(i\lambda_{k,l}a) \qquad I_k'(\lambda a)=[dI_k(x)/dx]_{x=\lambda a}$$

$$S'(a)=\sqrt[4]{1-\nu^2}[I_k'(\lambda_{k,l}a)+iC_{k,l}I_k'(i\lambda_{k,l}a)].$$

Substituting the four constants, given by (15), into the boundary conditions (3), (4), we obtain the system of the frequency equations. In order to simplify the latter system of equations we shall introduce two sets of abbreviations. The first set refers to the idealized blades of the system represented in Fig. 2 and consists of the formulæ

$$g_j=M_j:M \qquad (j=1,2,3), \tag{16}$$

$$\left.\begin{array}{l} G_1^*(\lambda a)=\sqrt{1-\nu^2}\lambda^2 f a^2 g_2 I_k(\lambda a) \\ \qquad\qquad +\sqrt[4]{(1-\nu^2)^3}f\lambda^2a^2(g_1-g_3)I_k'(\lambda a) \\ G_1^*(i\lambda a)=\sqrt{1-\nu^2}\lambda^2 f a^2 g_2 I_k(i\lambda a) \\ \qquad\qquad +\sqrt[4]{(1-\nu^2)^3}f\lambda^2a^2 i(g_1-g_3)I_k'(i\lambda a) \\ G_2^*(\lambda a)=f\lambda^3a^3[\sqrt[4]{1-\nu^2}(g_1+g_3)I_k(\lambda a) \\ \qquad\qquad +\sqrt{1-\nu^2}g_2I_k'(\lambda a)] \\ G_2^*(i\lambda a)=f\lambda^3a^3[\sqrt[4]{1-\nu^2}(g_1+g_3)I_k(i\lambda a) \\ \qquad\qquad +i\sqrt{1-\nu^2}g_2I_k'(i\lambda a)], \end{array}\right\} \tag{17}$$

in which the substitution of $i\lambda a$ for λa must be carried by definition, namely by virtue of the formulæ (14), (15), and (16), to the quantities g_j as well; [15] the second set of abbreviations refers to the part Γ of the system represented by Fig. 2; the expressions concerned are well known [16] from the original theory of Kirchhoff:

$$\left.\begin{aligned} G_1(\lambda a) &= (1-\nu)[-\lambda a I_k'(\lambda a) + k^2 I_k(\lambda a)] \\ &\qquad - \lambda^2 a^2 I_k(\lambda a) \\ G_1(i\lambda a) &= (1-\nu)[-i\lambda a I_k'(i\lambda a) + k^2 I_k(i\lambda a)] \\ &\qquad + \lambda^2 a^2 I_k(i\lambda a) \\ G_2(\lambda a) &= \lambda^3 a^3 I_k'(\lambda a) \\ &\qquad + (1-\nu)k^2[\lambda a I_k'(\lambda a) - I_k(\lambda a)] \\ G_2(i\lambda a) &= i\lambda^3 a^3 I_k'(i\lambda a) \\ &\qquad + (1-\nu)k^2[i\lambda a I_k'(i\lambda a) - I_k(i\lambda a)]. \end{aligned}\right\} \tag{18}$$

In using the two sets of symbols given in (17) and (18) the boundary conditions (3), (4) may be written in the form

$$\left.\begin{aligned} C_{k,l} &= -\frac{G_1(\lambda a) - G_1^*(\lambda a)}{G_1(i\lambda a) - G_1^*(i\lambda a)}; \\ C_{k,l} &= -\frac{G_2(\lambda a) + G_2^*(\lambda a)}{G_2(i\lambda a) + G_2^*(i\lambda a)}. \end{aligned}\right\} \tag{19}$$

The solution of this system of equations is given below for the case of $k = 2$, $l = 0$, and $f = 1$. The procedure of solution is as follows. Assuming a certain value for $\lambda_{2,0}a$ (the largest possible value of this constant is 2.32; it is obtained in the case of a disk without blades) we have to find by trial the value of μ in (14) in such a way that the two functions in (19) are indeed equal to each other; the common value of the two fractions is $C_{2,0}$; then we have, to the chosen value of $\lambda_{2,0}a$, the corresponding values of $\delta a/a$, g_1, g_2, g_3, and thus the constants (15) of the expression in the second brackets in (11). The system of the constants indicated determines the solution. For $k = 2$, $l = 0$ we obtain the set of constants given in the following Table 1.

[15] The necessary formulæ can be found f.i. in E. Jahnke und F. Emde, "Funktionentafeln mit Formeln und Kurven," B. G. Teubner, Leipzig, 1923.

[16] See f.i., "Handbuch der Physik," Vol. VI, Julius Springer, Berlin, 1928, p. 385.

TABLE I.

Solution of the Frequency Equations (19) *for* $k = 2, l = 0$.

$\delta a/a$.	$C_{2,0}$.	μ.	$\lambda_{2,0a}$.	$(\lambda_{2,0a})^2$.	$5.38(1+\delta a/a)^{-1}$.
0.000	−0.210	0.00	2.32	5.38	5.38
0.045	−0.225	0.10	2.20	4.84	4.95
0.127	−0.236	0.26	2.00	4.00	4.25
0.288	−0.270	0.49	1.70	2.89	3.18

According to this table we shall have, for $\delta a/a = 0.288$, $k = 2$, $l = 0$, $f = 1$, a vibration form of the disk represented by the formula

$$I_2\left(1.70\frac{r}{a}\right) - 0.27 I_2\left(1.70\frac{r}{a}i\right),$$

the corresponding vibration form of the blade being given, with $\lambda^* \cong \lambda$, by the expression

$$0.338 \sin\left(1.70\frac{r^*}{a}\right) + 0.170\cos\left(1.70\frac{r^*}{a}\right) + 0.086\sinh\left(1.70\frac{r^*}{a}\right) + 0.236\cosh\left(1.70\frac{r^*}{a}\right).$$

The vibration form of the entire system consisting of wheel and blades is given in Fig. 4; the vibration form of the blade

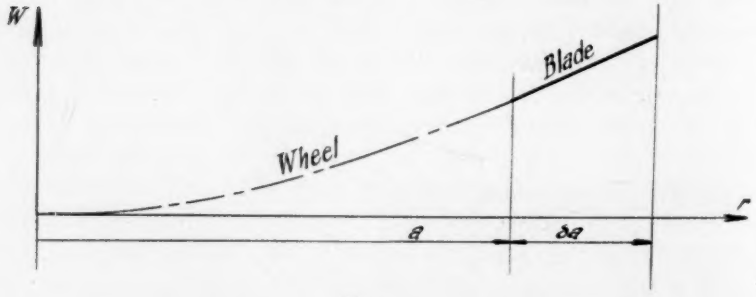

FIG. 4.

is practically a straight line.

The diagram Fig. 5 (bold line, thus far computed for the left part of the chart) represents the vibration frequency of

the combined system as a function of the ratio $\delta a/a$. The vibration frequency of the *solid* disk (i.e. one without blades) of the diameter $2a(1 + \delta a/a)$ is plotted in this diagram as

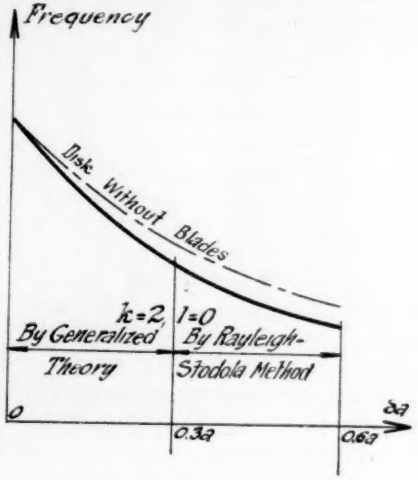

FIG. 5.

well for comparative illustration. This latter curve is determined by the formula

$$\text{frequency} = 5.38\,\frac{\text{const.}}{(1 + \delta a/a)^2},$$

wherein the factor $5.38 = 2.32^2$ (see the above Table 1) characterizes the frequency of the disk without blades.

(To be continued in the November issue.)

Turbines Generate By-Product Power From Refinery Process Gases.—JOHN GOLDSBURY AND J. R. HENDERSON. (*National Petroleum News*, Vol. 34, No. 30.) This is a portion of a paper published under the title "Turbines for Power Generation from Industrial-Process Gases," in the *Transactions of the A. S. M. E.* It makes reference to a 3500 hp. flue-gas turbine designed to be installed out-of-doors. The most important development so far in the use of turbines, driven by industrial-process gases other than steam, is found in connection with certain catalytic petroleum refining processes. In these processes carbon must be burned off and the catalyst regenerated at frequent intervals. In several of these processes, it is apparently most effective and economical to burn off the carbon under pressure. In some cases, the pressure is as high as 300 psi, and much higher pressures have been proposed. Several catalyst retorts are frequently used so that one or more can be undergoing the regeneration processes continuously. The maximum regeneration temperature is controlled either by tubes through which a coolant is passed, or by recirculation of some of the products of combustion which have passed through a waste-heat boiler, or by other suitable means. There is, then, a steady flow of these products of combustion or flue gas which is of no further use to the process. The heat could, of course, be partially recovered in a waste-heat boiler or other type of heat exchanger, but the pressure potential would be largely wasted. The pressure potential can be utilized and a large portion of the heat removed by passing the gas through a turbine. Not only may it be found that the use of a turbine will improve some established processes or increase the economy of operation, but the possible advantages of a turbine may turn the balance in favor of new processes being considered.

R. H. O.

THE MECHANISM OF NORMAL FOG FORMATION IN HYDROQUINONE DEVELOPERS.*

BY

T. H. JAMES.

A certain amount of unselective reduction of the silver halide occurs during the development of most photographic emulsions. This "fog" production acts as a limiting factor in the time of development, and may interfere with the achievement of shadow detail. The importance of fog control in the practice of photography scarcely needs to be emphasized. However, the amount of material pertinent to a study of the mechanism of fog formation is small.

The existence of different kinds of fog is well known. Dundon and Crabtree [1] suggest the following classification. (1) Emulsion fog, which results from the presence of "developable" grains in the unexposed emulsion. (2) Aerial fog, which results from aerial oxidation of the developer in contact with the emulsion. (3) Chemical development fog, which may be "merely a non-selective reduction, such as occurs with silver halides without the presence of gelatin, or reduction preceded by a nucleation effect which is the result of a chemical property of the developer." (4) Solvent fog, such as dichroic fog, "which is the result of physical development by silver dissolved in the developer due to the presence of a silver solvent such as sulfite or ammonia." (5) Light fog, caused by accidental exposure to actinic light.

The preceding listing contains several causes of fog which are secondary and accidental. Light fog is merely the accidental production of a latent image by light action, and development of this latent image proceeds in the normal way. Aerial fog is a secondary and controllable type which occurs, if at all, only in the presence of oxygen. Certain impurities sometimes present in the developing solution may promote

* Communication No. 865 from the Kodak Research Laboratories.

[1] M. L. Dundon and J. I. Crabtree: *B. J. Phot.*, 71, 701, 719 (1924).

fog. Cupric and sulfide ions are examples. Cupric ion is especially bad in promoting aerial fog. Sulfide may be formed in the developing solution under the proper conditions by the action of certain bacteria upon the sulfite normally contained in the developer.[2] These types of fog are of limited occurrence.

In the absence of such accidental and secondary causes, two fundamentally distinct reactions leading to normal fog may be foreseen from the results of previous studies on the reactions which occur between silver salts and developing agents.[3]

(1) A direct attack by the developing agent upon silver ions in solution or upon unnucleated silver halide surface.
(2) The catalytic action of pre-existing nuclei of silver sulfide (with or without metallic silver) originating in the ripening process during the manufacture of the photographic emulsion.

Reaction (1) by itself should produce little silver during the course of normal development. However, it could under proper conditions form nuclei of high catalytic activity. These nuclei may be formed on the grains by direct attack of the developing agent at the surface, or by deposition of silver from solution. Nuclei may also be formed away from the grains by the reaction between the developing agent and silver ions in solution. Subsequent catalytic reduction of the grains nucleated or of silver ions from solution could give rise to appreciable fog.

Silver sulfide nuclei can be produced by cooking the silver bromide emulsion in the presence of gelatin which contains certain sulfur bodies such as the thiocarbamides.[4] The reaction between the sensitizer allyl thiocarbamide and silver bromide is known to be autocatalytic in character.[5] This fact

[2] M. L. Dundon and J. I. Crabtree: *Trans. Soc. Mot. Pict. Eng.*, No. 19, 28 (1924).

[3] T. H. James and G. Kornfeld: *Chem. Rev.*, **30**, 1 (1942).

[4] S. E. Sheppard: *Phot. J.*, **65**, 380 (1925). See also T. Thorne Baker: "Photographic Emulsion Technique," American Photographic Publishing Co., Boston, 1941.

[5] B. H. Carroll and D. Hubbard: *Bur. Stand. J. Research*, **12**, 329 (1934).

is probably responsible for the high efficiency of the sensitizing action of this agent. The autocatalytic character of the reaction favors the formation of discrete nuclei. The optimum sensitizing effect may be obtained when the ratio of silver sulfide to silver bromide is no greater than 1 to 50,000. If the sulfide ratio is much greater than this, serious fog may result upon normal development. It may be expected that any high sensitivity emulsion will contain some grains which, without preliminary exposure to light, will be attacked readily by a normal developer because of the presence of silver sulfide nuclei of sufficient catalytic activity. Such grains appear as fog. Further, this type of fog need not be confined to high sensitivity emulsions, since only emulsions of rather special type are prepared with inert gelatin or without at least some ripening.

Although the production of fog by reactions of types (1) and (2) was previously recognized, the characteristics of the reactions had not been worked out experimentally. The present investigation shows that the kinetics of the sulfide catalyzed reaction are quite similar to those of the latent image catalyzed reaction, and that these in turn differ sharply in some respects from the kinetics of the uncatalyzed reaction of type (1).

EXPERIMENTAL CHARACTERISTICS OF THE REACTION TYPES.

Two special emulsions were employed in the study of the two reaction types. Emulsion "A" was an unripened pure silver bromide material prepared from inert gelatin. This emulsion contained no nuclei of silver sulfide or silver. Emulsion "B" was a pure silver bromide material which had been ripened in the presence of a sulfur sensitizer to a point where appreciable fog was obtained on normal development. The rate of fog formation with this emulsion was considerably greater than that with Emulsion "A," and the fog can be attributed to the action of sulfide nuclei. The third emulsion employed, "C," was a commercial normal motion picture positive material.

Hydroquinone was the developing agent used in most of the work, and its action could be studied either in the presence or absence of sodium sulfite by carrying out the work in the

absence or practical absence of oxygen. In order to separate the uncatalyzed reaction which initiates the fogging action in Emulsion "A" from the subsequent catalytic reaction, a special procedure was employed. The film was immersed in the hydroquinone solution for various times which were sufficiently short so that little or no *visible* fog was produced. The film was then thoroughly rinsed in water and the fog was intensified to a point where density of silver determinations could be made accurately. This intensification was standardized, and its validity checked by control experiments made without intensification. Experimental details are given in the last section of the paper. Reaction rates are expressed in terms of R, derived from the slope of the reaction curve at a given degree of reaction, and in terms of the reciprocal of the time, t, required to obtain an optical density of 0.05 for emulsion "A" or 0.10 for "B" and "C."

Characteristics of Fog in Emulsion "B."—The kinetics of fog formation with Emulsion "B" exhibit the general characteristics of a catalytic reaction similar to that of latent image development.[6,7] A well-defined induction period is observed (Figs. 1 and 2). Additions of sodium sulfite and resorcinol to the hydroquinone solution considerably decrease the rate of fog formation in both cases. This effect is due to the reaction between the added agent and the quinone formed during the fogging process. Sulfite is more efficient than resorcinol in this respect, and Figure 1 shows that identical results are obtained with 0.005M. sulfite and 0.02M. sulfite. The addition of quinone to the hydroquinone solution decreases the induction period of the fog formation, as in the case of development. Quantitative study of the quinone effect could not be made because the quinone decomposes rather rapidly in the alkaline solutions employed.

Characteristics of the electric barrier effect were observed in the fogging reaction. The reaction showed a high sensitivity to bromide, and small additions of bromide affected chiefly the induction period. At higher concentrations of bromide, distortion of the entire curve was observed (Fig. 2). Phenosafranin, which acts to decrease the zeta potential of

[6] T. H. James: *J. Phys. Chem.*, **43**, 701 (1939).
[7] T. H. James: *J. Phys. Chem.*, **44**, 42 (1940).

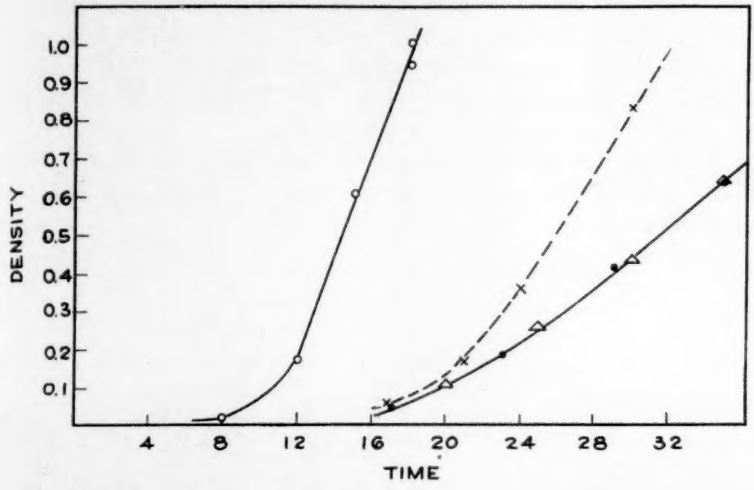

FIG. 1. Effect of sulfite on fog in Emulsion "B." Hydroquinone, 0.01M.; pH, 9.41. ○ ○, No addition; △ △, 0.005M. Na_2SO_3; ● ●, 0.020M. Na_2SO_3; × ×, 0.010M. Resorcinol.

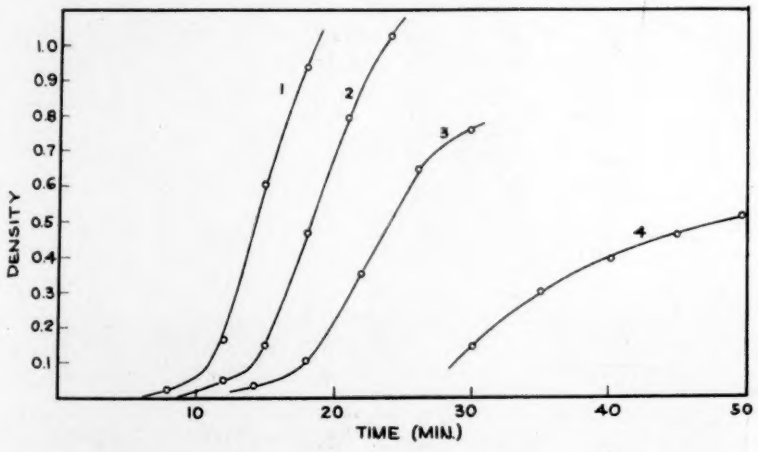

FIG. 2. Effect of Br^- on Fog in Emulsion "B." Hydroquinone, 0.01M.; pH, 9.41. Curve 1, no added Br^-; Curve 2, 2×10^{-5}M. Br^-; Curve 3, 4×10^{-5}M. Br^-; Curve 4, 1×10^{-4}M. Br^-.

the silver bromide grains, decreases the induction period. The fogging reaction is more sensitive to both bromide and phenosafranin than the development reaction, particularly beyond the induction period, but the differences appear to be quantitative rather than qualitative.

The fogging rates of substituted hydroquinones fall in the same order as the development rates. This is shown for selected examples in Table I.

TABLE I.

Variation of Rate with Substituent for Emulsion "B."
Reducing agent, 0.01M.; pH, 9.41; Na_2SO_3, 0.005M.

Agent	Fog Rate R	Fog Rate $1/t$	Dev. Rate R, pH 8.9	$-\pi_0$
Hydroquinone	0.04	0.051	0.020	−0.696
Toluhydroquinone	.07	.11	.039	− .641
Chlorhydroquinone	.12	.13	.089	− .710
Dichlorhydroquinone	.15	.22	.146	− .704

The kinetics of fog formation in Emulsion "B" are sufficiently similar to those of latent image development to justify the belief that the reaction mechanism in the two cases is fundamentally the same. The silver sulfide nuclei appear to be inferior to silver nuclei in catalytic activity, and show a greater sensitivity to bromide, but these are secondary differences.

Results with Emulsions "A" and "C." Emulsions "A" and "C" gave quite similar results, and will be considered together. The kinetics of the type of fog formation encountered with these emulsions are quite different from those with Emulsion "B." The most striking difference is to be found in the effect of sulfite and resorcinol. As shown in Figs. 3 and 4, these agents definitely *increase* the rate of fog formation with Emulsions "A" and "C," in contrast to the *decrease* obtained with Emulsion "B." In each case, however, the effect is due to reaction between the added agent and the quinone. The quinone has just the opposite effect upon the fogging reactions of the two types involved. In the catalytic mechanism ("B") the quinone accelerates the reaction initially either by action upon the electric barrier of the grain or by a semiquinone catalysis of the type which operates

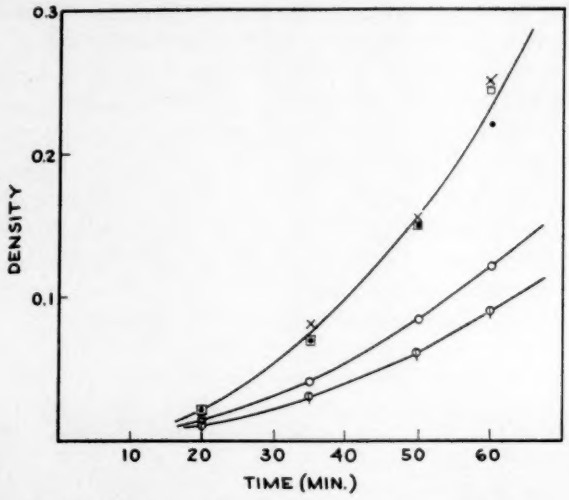

FIG. 3. Effect of Sulfite on Fog in Emulsion "A." Hydroquinone, 0.02M.; pH, 9.38. ○ ○, No addition; □ □, 0.0025M. Na_2SO_3; ● ●, 0.0050M. Na_2SO_3; × ×, 0.010M. Resorcinol; ϕ ϕ, 0.001M. Quinone.

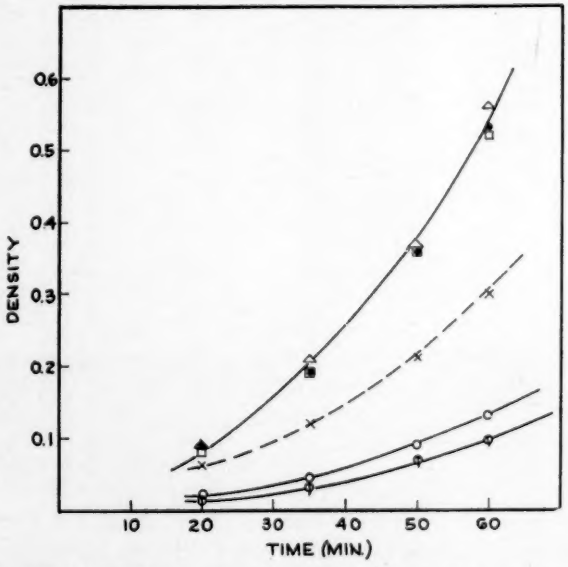

FIG. 4. Effect of Sulfite on Fog in Emulsion "C." Hydroquinone, 0.02M.; pH, 9.38. ○ ○, No addition; □ □, 0.0025M. Na_2SO_3; ● ●, 0.005M. Na_2SO_3; △ △, 0.020M. Na_2SO_3; × ×, 0.010M. Resorcinol; ϕ ϕ, 0.001M. Quinone.

in the oxygen oxidation of durohydroquinone.[8] In the non-catalytic mechanism ("A" and "C") the oxidizing action of the quinone upon silver supplies the probable explanation. Only a small amount of oxidation of the finely divided silver may decrease the rate of formation of *active* catalysis centers, or destroy the activity of small ones already formed, and thus seriously retard the subsequent "intensifying" catalytic reaction. The explanation of the sulfite effect observed by Mees and Piper in their work on the fogging properties of hydroquinone solutions [9] thus becomes clear. No complex formation between hydroquinone and sulfite is involved.

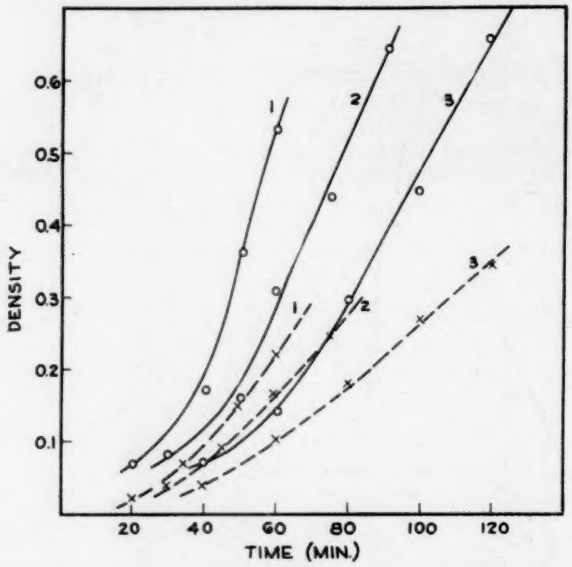

FIG. 5. Effect of Br^- on Fogging Rate in Emulsions "A" and "C." Hydroquinone, 0.02M.; Na_2SO_3, 0.005M.; pH, 9.38. —×—×— Emulsion "A"; —○—○— Emulsion "C." Curve 1, No added Br^-; Curve 2, 2×10^{-5}M. Br^-; Curve 3, 1×10^{-4}M. Br^-.

There is no evidence of an electric barrier effect. Phenosafranin produces a slight decrease in fog rate. The effect of added bromide is shown in Fig. 5. In this case, the bromide

[8] T. H. James and A. Weissberger: *J. Am. Chem. Soc.* **60**, 98 (1938).

[9] C. E. K. Mees and C. W. Piper: *Phot. J.*, **51**, 226 (1911); **52**, 221 (1912).

produces a uniform decrease in rate throughout the measured portion of the reaction curve, and the effect is considerably smaller than that observed with Emulsion "B." The decrease in reaction rate, further, is considerably smaller than the decrease produced in the equilibrium silver ion concentration which the silver bromide could supply to solution.

A comparison of the effects of pH and hydroquinone concentration upon the rate of fog formation (Table II) shows that the divalent ion is the species active in the reaction. The procedure used to correlate the reaction rate with a specific ionic form has been described previously.[7]

TABLE II.

Variation of Fog Rate with Concentration and pH.
Na_2SO_3, 0.005M.

Hydroquinone Conc.	pH	Emulsion "A"		Emulsion "C"	
		R	$1/t$	*R*	$1/t$
0.0025	9.38	0.00225	0.017	0.0057	0.018
.0050	9.38	.00305	.024	.0073	.022
.0100	9.38	.0045	.031	.0093	.033
.0200	9.38	.0065	.038	.0130	.043
.0300	9.38	.0080	.047	.0156	.052
.0200	9.04	.0030	.024	.0076	.029
.0200	8.91	.0022	.019	.0059	.022

A reasonably straight line is obtained by plotting the logarithm of the rate against the logarithm of the hydroquinone concentration. The slopes of the straight lines obtained for the two emulsions and the two different measures of the reaction rate lie in the range of 0.42 to 0.53. This suggests that the active ion is adsorbed to the silver bromide prior to reaction. There is considerable indirect evidence that adsorption of hydroquinone from alkaline solution occurs,[10,11] and such adsorption would account for the linear log-log relationship.

The most probable mechanism for the formation of fog in emulsions "A" and "C" involves the direct reaction between adsorbed divalent hydroquinone ions and the silver

[10] S. E. Sheppard and G. Meyer: *J. Am. Chem. Soc.*, **42**, 689 (1920).
[11] P. Wulff and K. Seidl: *Z. wiss. Phot.*, **28**, 239 (1930).

ions at the points of adsorption. When the silver produced in this way is sufficient to form a catalytic center in a given grain, further reduction will proceed predominantly by the catalytic mechanism of development. The rate of fog formation under normal conditions, however, will be governed mainly by the rate of formation of the catalytic centers and hence by the rate of the initial uncatalyzed reaction.

The fogging rates of a series of substituted hydroquinones was measured with both emulsions. The results are given in Table III. The reaction curves obtained were in most cases

TABLE III.

Variation of Fog Rate with Substituent.

Na_2SO_3, 0.005M.; pH, 9.41; Reducing Agent, 0.01M.

Agent	$-\pi_0$	Em. "C" $1/t$	Em. "A" $1/t$	Dev. Rate pH 8.9
Gentisic Acid	−0.793	0.0065	—	—
Gentisic Acid Methyl Ester	− .793*	.014	0.014	—
Bromhydroquinone	− .712	.033	.032	0.109
Chlorhydroquinone	− .710	.033	.034	.089
Dichlorhydroquinone	− .704	.039	.040	.146
Hydroquinone	− .696	.040	.035	.020
Toluhydroquinone	− .641	.111	.052	.039
p-Xylohydroquinone	− .587	.58	.092	.085

* Value for the *ethyl* ester.

of the same form as those of hydroquinone. However, when emulsion "C" was employed, the curve for toluhydroquinone was less concave and those for the xylohydroquinones were even convex in form.

The data show that there is no correlation between the fog rates and the development rates. On the other hand, the fog rates fall in the same order as the negative values of the normal redox potentials ($-\pi_0$). Thus, the more powerful the reducing agent of the hydroquinone series, the greater the fogging rate. If the logarithms of the fog rates are plotted against $-\pi_0$, the curves shown in Fig. 6 are obtained.

The redox potential—fogging rate relationship was tested with Emulsion "C" for six members of the hydroquinone series employed in a conventional test developer solution at pH 10.2. The fog rates given in Table IV are in terms of density units per minute, and no intensification procedure

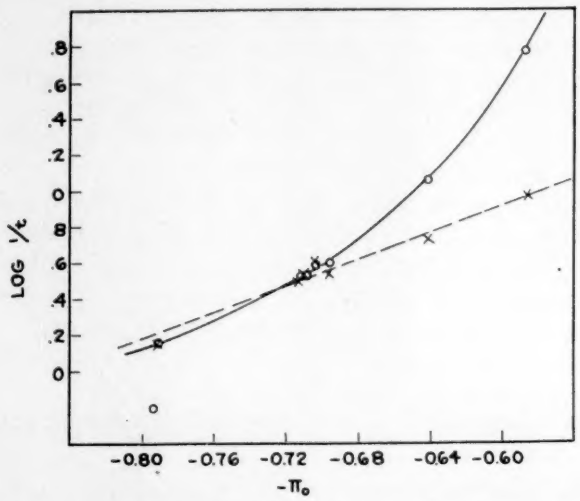

FIG. 6. Relation Between Fogging Rate and Redox Potential.
—×—×— Emulsion "A"; —○—○— Emulsion "C."

TABLE IV.

Variation of Fog Rate with Substituent for a Conventional Developer.

Agent	$-\pi_0$	Em. "C" R
Gentisic Acid Methyl Ester	−0.793	0.008
Chlorhydroquinone	− .710	.021
Hydroquinone	− .696	.025
Toluhydroquinone	− .641	.040
Hydroxyhydroquinone	− .591	.080
m-Xylohydroquinone	− (.587)	.10

was employed. Once more, the same order prevails for fog and $-\pi_0$.

The observed relationship between redox potential and the rate of the uncatalyzed fog-producing reaction is not wholly unexpected from a theoretical standpoint. The reaction is probably of a relatively simple type. Under the conditions employed in this work, the normal redox potential should be a linear function, at least approximately, of the total free energy change of the reaction. If, now, the reaction is considered in terms of the intermediate "activated" complex, it may be shown that, for a specific hydroquinone, the reac-

tion rate is a function of the *free energy of formation of the activated complex*. For a simple series of derivatives of hydroquinone such as that employed (with the exception of gentisic acid, where complications arise) the free energy of formation of the activated complex is probably nearly proportional to the total free energy of the reaction.

The linear relationship observed between the redox potential and the logarithm of the rate of fogging of Emulsion "A" may be derived by an admittedly over-simplified treatment of the reaction mechanism. The formation of the activated complex may be treated as an equilibrium reaction with the equilibrium constant K^*.[12] In the absence of complications, the over-all reaction rate is proportional to the concentration of activated complex. Since this concentration is very small, we may write:

$$\text{Rate} = u \cdot K^*. \tag{1}$$

By making use of the normal relationship between equilibrium constant and free energy, Equation (1) may be rewritten in the form:

$$\text{Rate} = u \cdot e^{-\Delta F^*/RT}, \tag{2}$$

where ΔF^* is the free energy of formation of the activated complex. Following Eyring's notation,[12] u in Equation (2) may be replaced by the frequency factor $\alpha(kT/h)$, where α is a constant. By converting Equation (2) to logarithmic form, and substituting for ΔF^* a linear function of the redox potential, we obtain the relation:

$$\log \text{Rate} = A(-\pi_0) + B, \tag{3}$$

which is of the desired linear form.

No simple relationship is observed between redox potential and the development rate or the oxygen oxidation rate.[7] The catalysis factor in these reactions introduces a serious complication. Further complications in the development reaction may arise from the presence of the electric barrier effect. Even in the fog formation reaction under discussion, gentisic acid does not obey the simple relationship. Excluding gentisic acid, the plot of $(-\pi_0)$ against log Rate is linear

[12] Cf. S. Glasstone, J. K. Laidler and H. Eyring: "Theory of Rate Processes," McGraw-Hill, New York, 1941.

for Emulsion "A," but gives a smooth non-linear curve for Emulsion "C." Attempts to extend the relationship to include non-hydroquinone developing agents would almost certainly fail. The proportionality between ΔF^* and ΔF no longer could be expected to hold.

EXPERIMENTAL DETAILS.

The experimental work upon which this paper is based was carried out in an atmosphere of oxygen-free nitrogen at 20° C. The apparatus employed was similar in construction to that used previously in studies on development.[6] Hydroquinone solutions buffered in the pH range 8.9–9.4 were used. Agitation of the solution was supplied by the nitrogen. Optical densities were generally used as a measure of silver formed, since the photometric equivalent was reasonably constant under most of the conditions.

For the intensification procedure employed with Emulsions "A" and "C," a developer of the following composition was employed:

Elon	0.30 g.
Sodium Sulfite	40.0
Hydroquinone	6.0
Sodium Carbonate	20.0
Sodium Bicarbonate	2.0
Potassium Bromide	1.0
Water	1.0 liter

This solution produced no visible fog in Emulsion "A" within 8 minutes. The intensification was complete within 3 to 4 minutes, and further action of the solution produced no further change in density up to at least 8 minutes. As standard procedure, intensification was carried out for 5 minutes. Some primary fog was produced during intensification with Emulsion "C," but it was sufficiently small so that accurate correction could be made. Once more, intensification was complete within 4 minutes, and continued action of the solution up to 8 minutes added only primary fog.

ROCHESTER, N. Y.,
June 25, 1942.

New Lenses Eliminate Glare in Welding Aluminum.—(*Iron Age*, Vol. 150, No. 5.) Perfection of new welding goggles that will help speed up production of Hudson bombers and Lightning P-38 interceptors by entirely eliminating glare from aluminum welding operations, was announced at the Lockheed Aircraft Corp. These goggles will be made available to all airplane manufacturers. Aluminum welders have been severely handicapped by the glare from the hydrogen torches, which caused severe eyestrain and hid their work from direct view, making welding a difficult operation. This glare is caused by the low temperature at which aluminum melts, the high temperature of the hydrogen torch, and the large amount of flux required in this type of welding. This glare problem was solved by DR. R. C. BURT, a member of the Lockheed plant engineering department, who with the help of Corning glass works technicians, produced a pair of goggles with the optical properties that would filter out the glare. As now used by Lockheed welders, the improved lenses allow a small cone of flame to be seen at the burner tip. Not only has the work speeded up but some welding operators had never been able to read or attend movies because of headache and eye fatigue. Since they started wearing the new anti-glare lenses, they do either or both without ill effect. Dr. Burt attacked the problem from the filtering angle. An analysis of the flame indicated the undesirable rays, and, through a series of experiments, a combination of light filters was found which not only filtered out the undesirable rays but passed sufficient light of other wave-lengths to give good visibility of the work. From the absorption curve of this filter combination it was possible to select two glass filters which combined gave the desired results. After months of coöperative research, with Corning experts making glass samples and Dr. Burt cutting, grinding and testing, a pair of goggles was produced with all the desired optical properties.

R. H. O.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

COMMERCIAL STANDARD FOR CLINICAL THERMOMETERS.

The third edition of Clinical Thermometers, Commercial Standard CS1–42, has just been released. The revised requirements are somewhat higher than those of the previous standard, so that a few thermometers which would previously have been acceptable would now be rejected. The standard also provides that records of test results shall be kept on file by the manufacturer for at least two years after the test was made.

The standard covers materials, construction, and aging. It also prescribes in detail, methods for testing, such as a test for the pigment in the graduation marks, a test for entrapped gas in the bulb and mercury column, a test for difficulty in shaking the column down before using (hard shakers), tests for accuracy, and a test for retreating index. A form for certification is given. The pamphlet also includes a brief history of the project, a list of the personnel of the standing committee, and a list of acceptors. The revision became effective for new production on February 20, 1942. Copies of CS1–42 are obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 10 cents each.

A METHOD FOR DEVELOPING SPECIFICATIONS FOR BUILDING CONSTRUCTION.

To meet the demand for short and uniform specifications for Government building construction, and in an attempt to reduce the time and labor now consumed in their preparation, a representative committee of Federal agencies has made a study of current specification-writing routine. In its report, which is being published in the Building Materials and Struc-

* Communicated by the Director.

tures series as BMS87, this Committee advocates a directive method which, under proper supervision, should condense specifications, bring about important economies, and increase efficiency.

Fundamental principles that have proved of value over a period of years have been retained and are coördinated in a basic specification which promotes uniformity and permits choice of those materials and methods of construction best suited to the specific project in hand. Application of the method is made clear by three examples: A model basic specification illustrating the procedure outlined, a typical contemporary specification, and the typical specification rewritten in accordance with the method advocated.

Copies of BMS87 are obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 10 cents each.

PROPERTIES OF "SPEEDBRIK" WALL CONSTRUCTION.

Building Materials and Structures Report BMS86, which was released a short time ago, gives the results of structural, heat-transfer, and water-permeability tests on specimens of "Speedbrik" masonry wall construction submitted by the General Shale Products Corporation for structural, heat-transfer, and water-permeability tests.

The structural specimens were subjected to compressive, transverse, concentrated, impact, and racking loads, for each of which three like specimens were tested. The transverse, concentrated, and impact loads were applied to the inside face of the specimens. The deformation under load and the set after the load was removed were measured for each increment of load.

Heat-transfer properties of two specimens were determined in a shielded hot-box heat-transfer apparatus, and nine water-permeability specimens were tested under conditions that simulated exposure to a heavy wind-driven rain.

Copies of BMS86 are obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 15 cents each.

PERFORMANCE REQUIREMENTS FOR SOUND MOTION PICTURE PROJECTORS.

The prospective purchaser of 16 millimeter sound motion picture projectors is often confronted with the preparation of a specification which will insure the purchase of equipment having good performance at reasonable cost. Aside from performance standards, which should approach 35 mm. performance wherever possible, other factors such as compactness, portability, ruggedness, simplicity, and reliability are important.

It is desirable that specifications be prepared from the viewpoint of objective tests. The overall performance of the complete sound system will indicate, in large measure, the operating characteristics of a projector. However, at present, certain difficulties and lack of suitable test film prevent direct measurement of some of these characteristics.

In Circular C439 Wilbert F. Snyder discusses, in detail, the performance requirements of high-grade 16 mm. sound motion picture projectors. Suitable test methods are described which can be duplicated by large school systems and other agencies with technical departments. Particular treatment is given to the overall response-frequency characteristic, signal-to-noise ratio, harmonic distortion, flutter measurement, directional characteristic of loudspeaker, and noise of operating mechanism. Simplified methods of sound measurement are described. Results of tests of six representative projectors are included.

Comments are made on the present-day performance of 16 mm. projectors and possible improvements are suggested. A liberal amount of background material has been included and a list of literature references indicates additional source material.

Copies of C439 are obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 15 cents each.

WIDE ANGLE AIRPLANE-CAMERA LENSES.

The tendency toward the more extensive use of wide angle photographic objectives in airplane mapping cameras

makes it desirable for the Bureau to have on hand as much information about their performance as possible. Measurements to secure the needed data have, therefore, been made by Francis E. Washer of the optical instruments section. The lens characteristics that are of principal interest to the user are relative illumination in the focal plane, resolving power, and distortion. The matter of variation in the amount of light reaching different portions of the focal plane is most important since the usefulness of a given negative is markedly reduced when the center must be so far overexposed as to impair definition in order to get photographic density at the edge sufficient to distinguish detail. The relative illumination is governed by several factors. Geometric considerations alone show that the maximum illumination in the focal plane for regions separated by 45° from the axis is 25 per cent. of that on the axis in the ideal case. Vignetting or encroachment of the lens boundary into the transmitting area of the lens reduces the relative illumination still more, and during the course of this study an additional factor which depends upon the lens design was found to be operative in reducing the relative illumination for some lenses.

The performance of a number of typical wide angle lenses, with particular emphasis on relative illumination in the focal plane, resolving power, and distortion, together with a description of the methods used and tabulation of the results obtained, are given in RP1498 in the September number of the *Journal of Research*.

TRIPLE POINT OF WATER AS A BASIC FIXED POINT.

The "ice point," or freezing point of water, has been the basic fixed point in nearly all measurements of temperature. For work of highest precision, however, it is desirable to avoid the small variations in the ice point resulting from contact of the ice with the atmosphere. For this purpose the triple point, that is the temperature at which ice and water are in equilibrium with pure water vapor, has advantages. A direct comparison between the ice point and the triple point for the same sample of water shows a difference of 0.00997° C.

The fortunate coincidence that this difference is 0.01°, within the accuracy of measurement, may permit the convenient use of the triple point as 0.01° in place of the ice point in precision measurements.

PROVISIONAL pH STANDARDS.

The efficiency and rapidity of many processes involved in the preparation of commercial products depend upon the accurate control of the acidity or alkalinity of aqueous solutions. Such control is now a legal requirement in certain medicinal preparations, in the manufacture of paper and leather for the Government, and in many Federal specifications. Water and sewerage purification; boiler water control; dry-cleaning of garments, furs, and rugs; and the manufacture of disinfectants and insect sprays, chemicals and explosives, lubricating oils and greases, textiles, canned foods, and a host of other products depend upon test and control of acidity for their success. The processing of milk and cheese, the purification of many organic solvents, tanning and pulping operations, mineral flotation and refining, electroplating, and printing and lithographing also require the regulation of acidity. In fact, products valued at over 40 billion dollars are manufactured annually under conditions of controlled acidity.

Roger G. Bates, Walter J. Hamer, George G. Manov, and S. F. Acree, of the Bureau's pH Standards Section are engaged in devising and improving methods for the accurate measurement of acidity, designated by a number called the "pH value," and have recommended 17 standard solutions of a wide range of known acidities for the use of those workers who need to determine pH with precision. As explained in the September *Journal of Research* (RP1495), these standards are intended to be employed in adjusting to a common basis equipment now in use for pH determinations and for the control of acidity in laboratory reactions and industrial processes. Directions are given for the preparation of the solutions, and the pH values at 20°, 25°, and 30° C. are listed.

SURFACE OF BONE BLACK AND OTHER ADSORBENTS.

The usefulness of a porous material as an adsorbent depends principally upon the extent of its surface and the accessibility of that surface to the molecules which are to be adsorbed. The surface is generally much greater than the apparent surface and, obviously, parts of it may be accessible only to small gas molecules. Such minute units must serve as a measuring standard if the total surface is to be determined. An investigation of the surface areas of carbonaceous adsorbents is described in a paper in the September *Journal of Research* (RP1496) by Victor R. Deitz and Leland F. Gleysteen, Research Associates stationed at the Bureau by the United States cane sugar refiners and bone black manufacturers.

The method used to determine the surface depends upon the adsorption of nitrogen at low temperatures. The adsorption was found by measuring the pressure decrease of a known volume of the gas exposed to each of 20 different samples of bone blacks, activated carbons, vegetable carbons, and coconut charcoals. The specific surface was deduced by the analysis of these data with the aid of the multimolecular theory of adsorption. Typical examples of the results show a surface of 120 square meters per gram or about 2 square miles per 100 pounds, for a sample of new bone char and an area of 1,700 square meters per gram or about 30 square miles per 100 pounds, for a coconut-shell charcoal. The ratio of the surface of a new bone char to that of a spent bone char may be as great as 7, with corresponding values for the intermediate cases of the service chars. The error of the method as a means of measuring such surfaces is placed approximately at 20 per cent. for absolute determinations, but it may be as small as 5 per cent. for relative determinations.

From the data at liquid nitrogen temperatures it is possible to discuss the distributions of pore sizes in the adsorbents. The data are divided into 5 groups, each characterized by a value of n, which is defined as the maximum possible number of adsorbed layers on the surface of the pores of the material. All the samples of each group have a common isotherm when reduced to unit surface. For example, the bone chars, which

may show as much as the seven-fold variation in surface mentioned above, show the same adsorption per unit surface at a given relative pressure. The adsorption at 77° K. is considered from the standpoint of capillary condensation. The volume, as adsorbed liquid nitrogen, is plotted against the corresponding radius of a cylindrical capillary which is determined from the Kelvin equation, and the distribution of capillaries is discussed from these considerations. The differential heats of adsorption are also determined from the data.

PREPARATION OF LOWER ALDONIC ACIDS.

Small quantities of the lower aldonic acids are occasionally required for investigations in the fields of biological and organic chemistry. Heretofore, specific directions for the preparation of these substances were not available and hence these acids were difficult to obtain. Directions given by Horace S. Isbell in the September *Journal of Research* (RP1497) for the preparation of *l*-erythronic, *d*-threonic, *l*-xylonic, *d*-lyxonic and *d*-arabonic acids make their production relatively simple.

The acids are prepared by the oxidation of certain sugars with oxygen in alkaline solution. In the process, carbon 1 of the sugar is removed and the salt of the lower sugar acid is produced. The yield of lower acid varies from 30 per cent. for *d*-lyxonic acid to 70 per cent. for *d*-arabonic acid. *l*-Erythronic, *d*-threonic and *l*-xylonic acids are obtained in about 45 per cent. yields. *l*-Erythronic and *d*-threonic acids were separated as brucine salts which crystallize in hydrated forms in addition to the previously known anhydrous forms. The optical rotations of brucine *l*-erythronate and brucine *d*-threonate were found to vary widely with concentration and to be of approximately equal value.

Alchemical Potions.—*The Industrial Bulletin* of Arthur D. Little, Inc. Number 180 states that one of the properties of radium, first observed over forty years ago, is its great capacity for acting as a destructive agent on the cells of the body. Doctors had long sought such a source of cell damage to be used cautiously so that disease could be killed, and gladly investigated radium as a useful drug. While radiation will damage all tissue, the normal tissue will recover. Techniques have been devised for the use of radium and its emanations, but these do not cover all desirable applications, especially in diffuse organs. With the new "Electron Drugs," the possibilities of radioactive treatment have been measurably extended. These new preparations have chemical properties that make the radioactivity seek out particular places in the body for its action, and if chosen correctly, have penetration power, type of radiation and effective length of life well adapted for the service. Whenever small amounts of iodine are taken into the body, a very large proportion of this element goes to the thyroid gland, in the neck, where it becomes part of the hormone "thyroxin." At the University of California Medical School, radiations of a radioactive form of iodine produced by a cyclotron have been reported successful on cases of toxic goiter, which is not curable with iodine per se. These radiations penetrate only one twenty-fifth of an inch, and, under the conditions of treatment, cleared up the goiters without damage to the rest of the body. Radio-phosphorus goes chiefly to the bone marrow, where blood corpuscles are being produced. Small doses of radio-phosphorus taken a few months apart have appeared to control the disease polycythemia, or excessive production of red blood cells. Radio-phosphorus is apparently about equal to X-ray for the treatment of leukemia, which is excessive production of white blood corpuscles or cells. It has an advantage over X-ray treatment which may cause radiation sickness. Strontium goes to the outer portions of the bones. A new radioactive form of strontium has been employed on hopeless cases of bone cancers with some abatement of symptoms reported. These examples may be only forerunners of other valuable new specific medicines.

R. H. O.

THE FRANKLIN INSTITUTE

LIBRARY NOTES.

The Committee on Library desires to add to the collections any technical works that members would wish to contribute. Contributions will be gratefully acknowledged and placed in the library. Duplicates received will be transferred to other libraries as gifts of the donor.

Photostat Service. Photostat prints of any material in the collections can be supplied on request. Orders received in the morning are filled the same day. The average cost for a print 9 × 14 inches is thirty-five cents.

The library and reading room are open on Mondays, Tuesdays, Fridays and Saturdays from nine o'clock A.M. until five o'clock P.M., Wednesdays and Thursdays from two until ten o'clock P.M.

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RESOLUTIONS PASSED BY THE BOARD OF MANAGERS ON THE OCCASION OF THE DEATH OF MR. CLARENCE A. HALL.

THE BOARD OF MANAGERS OF THE FRANKLIN INSTITUTE desires to record its sense of loss in the death on July 20, 1942, of CLARENCE ARTHUR HALL, and to convey to his family this expression of condolence.

Becoming a member of the Institute in 1902, he was elected to membership in the Committee on Science and the Arts in 1906, serving as Chairman of that

body in 1926, and receiving in 1940 the Hoadley Certificate after 35 years of faithful service. He was appointed a member of the Library Committee in 1914 and served for several years as its Chairman. His election to the Board of Managers occurred in 1922, and his appointment to the Committee on Publications followed in 1932. In 1934 he became Chairman of the Bartol Research Foundation Committee, and in 1939 was elected Assistant Treasurer of the Institute.

This very unusual diversity of interests afforded him a detailed and intimate knowledge of the workings of The Franklin Institute in all of its ramifications such as few of its members possess.

The happy combination of strict probity, untiring devotion to everything pertaining to the welfare of the Institute, unfailing willingness at all times to lend a helping hand, and a keen sense of humor, made him a particularly valuable member of the Board continuously over a period of twenty years, inevitably resulting in his being consulted frequently by fellow members concerning matters related to the progress and development of this time-honored organization which was so dear to him.

The Board of Managers desires to record in its Minutes this expression of sorrow and directs that a copy be forwarded to Mrs. Hall and that it be published in the JOURNAL OF THE FRANKLIN INSTITUTE.

September 17, 1942.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

The Bacteriostatic Agent of Penicillium chrysogenum.—LOUIS DESPAIN SMITH. Since the isolation of a bacteriostatic substance from a mold by Fleming (*British Journal of Experimental Pathology*, **10**: 226, 1929) various workers have investigated other molds, particularly those closely related to *Penicillium notatum*, the species to which Fleming's mold belonged. Clutterbuck, Lovell, and Raistrick (*Biochemical Journal*, **26**: 1907, 1932) were unable to find any production of bacteriostatic agent by four strains of *Penicillium chrysogenum* grown on modified Czapek-Dox medium, or by one known strain of *Pen. notatum*. Since the mold isolated by Fleming under similar conditions produced the bacteriostatic agent, penicillin, they concluded that its identity with *Pen. chrysogenum* or *Pen. notatum* was doubtful from a physiological point of view.

We found that *Pen. chrysogenum* produces a bacteriostatic substance which is similar to penicillin in biological action and in certain of its chemical characteristics.

MATERIALS AND METHODS.

Cultures of *Pen. chrysogenum* and *Pen. notatum* were isolated in this laboratory, and were identified by Dr. Charles Thom, of the United States Department of Agriculture.

In order to test the inhibition by mold products of the growth of bacteria, serial dilutions of culture fluids of the molds were made in tubes containing 5 ml. quantities of heart infusion broth. The tubes were then inoculated with 0.05 ml. of 18-hour cultures of the bacteria to be tested. Readings were made after these tubes had been incubated for 24 hours at 37° C.

The molds were grown on broth, in layers 2.5 to 3.0 cm. deep. When the medium was shallower or deeper than this, a smaller yield of the bacteriostatic agent resulted. When the bacteriostatic agent was to be isolated, the culture fluid

underlying the mycelium was poured off and filtered through cotton. No attempt was made to extract the mycelium.

EXPERIMENTAL.

It was found that any medium which contained more than 0.5 per cent. of readily fermentable carbohydrate could not be used, since the strains of *Pen. chrysogenum* and *Pen. notatum* formed acid so readily that the acidity of the medium became too high for the production of the bacteriostatic agent. Consequently, modified Czapek-Dox medium and similar nutrient fluids were found to be unsuitable although they served as excellent media for the growth, *per se*, of the molds. The negative findings of Clutterbuck, et al., can probably be ascribed to the fact that they grew the known strains of *Pen. chrysogenum* and *Pen. notatum* only upon modified Czapek-Dox medium.

Commercial peptone preparations and other media were tested for the production of bacteriostatic agent by *Pen. chrysogenum*. These were used in 2 per cent. solution, since preliminary experiments showed that for satisfactory production the peptone concentration should be between 1.5 per cent. and 3 per cent. Seventy-five ml. of medium were used in each 250 cc. Erlenmeyer flask. After inoculation with spore suspensions the cultures were immediately placed in the incubator, except those grown at 15° C., which were allowed to stand at room temperature for 48 hours before incubation to hasten germination of the spores. The inhibition of the growth of *Staph. aureus* by the culture fluid of *Pen. chrysogenum* grown on various media is recorded in Table I.

The results of similar experiments at 20° C., 25° C., and 30° C. indicated that 15° C. was the best temperature for the production of the bacteriostatic substance, although it was necessary to incubate longer at this lower temperature. It should be pointed out, however, that the total amount of bacteriostatic material produced by the mold is not indicated by the procedure used; only the amount of active material present at the time of the test is indicated. Because of the rather rapid inactivation of the bacteriostatic agent in slightly alkaline media at temperatures higher than 20° C. it is prob-

able that the lower temperatures were not so much more favorable for the actual production of the agent as that they were less favorable for its inactivation.

Whey broth, either freshly prepared or the dehydrated medium, was found to be the best medium for routine preparation of the active material. The change in pH was less with this medium than with any of the others. In a seven-day culture in whey broth, the pH was about 7.0; in a similar culture in 2 per cent. Neopeptone, the pH was about 8.0, while in modified Czapek-Dox medium, the pH was about 4.0.

TABLE I.

Inhibition of Growth of Staph. aureus by Culture Fluid of Pen. chrysogenum on Various Media at 15° C. for 7 Days.

Medium.	Dilution of Culture Fluid.				
	1 : 5	1 : 50	1 : 100	1 : 200	1 : 400
Brain-heart infusion (Difco)	+	+	+	±	−
Whey broth (Difco)	+	+	+	−	
Heart infusion (Difco)	+	+	+	−	
Neopeptone	+	+	+	−	
Tryptone	+	+	+	−	
Purple milk	+	+	±	+	
Witte peptone	+	+	−		
Yeast extract (Difco)	+	+	−		
Parke-Davis peptone	+	±	−		
Bacto-peptone	+	±	−		
Gelatin	+	−			
Proteose peptone	+	−			
Malt extract	−				
Fairchild and Foster peptone	−				
Armour peptone	−				

(+ denotes complete inhibition, ± almost complete inhibition, − little, if any, inhibition.)

The procedure used to purify the bacteriostatic agent was a modification of that described by Abraham, et al. (*Lancet*, p. 177, 1941). The broth underlying the mold mycelium was poured off, chilled, adjusted to pH 3.5 with phosphoric acid, and shaken twice with ether or amyl acetate. The ether or amyl acetate portions were combined and were shaken with 0.05 per cent. $Ba(OH)_2$ or else with water and a small amount of $BaCO_3$. The organic solvent was removed and the water solution was adjusted to pH 3.5 with H_2SO_4 and

shaken with two portions of ether, which were combined and used for the adsorption procedure.

The extraction was done as rapidly as possible, and both the water and the ether solutions were kept in the refrigerator except when actual manipulation was necessary. It was found to be harmful to adjust the water solutions of the active agent lower than pH 3.0, for there appeared to be some decomposition when the solutions were made more acid than this.

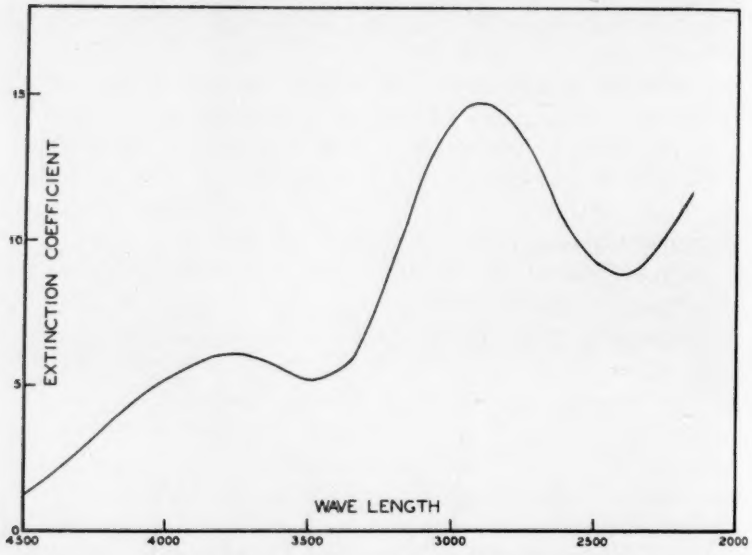
A portion of the ether solutions was passed through a column of a mixture of Brochman's alumina and Filter-Aid (equal parts by weight), followed by 200 to 300 ml. of ether. If only one band appeared, as was usually the case when the mold had not been incubated too long, or when the water solution or the broth had not been made too acid, or when the previous steps in the purification had been carried out at too high a temperature, the remaining ether solution was treated with successive portions of Brockman's alumina until practically all of the yellow color had left the supernatant ether and the alumina had become a bright orange-yellow in color.

The bacteriostatic substance was removed from the alumina by elution with successive small portions of phosphate buffer (pH 6.7, M/15), of 50 per cent. methyl alcohol, of 0.05 per cent. $Ba(OH)_2$, or of water to which a small amount of $BaCO_3$ had been added. When $BaCO_3$ was used, the excess was removed by filtration through paper. The solutions were adjusted to pH 6.7 when the material was to be kept for some time.

The bacteriostatic agent prepared in this way was quite similar in solubility to the penicillin investigated by Abraham, et al. and Abraham and Chain (*British Journal of Experimental Pathology*, **23**: 103, 1942) since in the acid form it was soluble in ether, amyl acetate, dioxane, and ethyl acetate. As the sodium, potassium, or barium salt it was soluble in water. From ether it could be adsorbed on alumina, from which it could be eluted with alkaline buffer. A slight precipitate formed when a water solution of the active agent was treated with a solution of ferric salt.

Meyer, et al. (*Science*, **96**: 20, 1942) reported that penicillin prepared by them had an absorption maximum at 2750 Å.

Holiday (*British Journal of Experimental Pathology*, **23**: 115, 1942) reported poorly defined maxima at 2470 Å and at 3000 Å. We found a maximum at about 2900 with the barium salt of the material isolated from culture fluid (Plate I). The determinations of the ultraviolet absorption spectrum were made by Miss Rachel Franklin, of this laboratory.



The sample of bacteriostatic agent used in the determination of the ultraviolet absorption, in a dilution of 1 : 4,500,000 inhibited the growth of three of four strains of *Staph. aureus*. The fourth strain grew slightly in this dilution. Such bacteriostatic potency corresponds roughly to 90–100 Oxford units per milligram, which is about the same as that reported by Abraham and Chain for penicillin at a similar stage in purification.

Whey broth cultures of *Pen. chrysogenum* and *Pen. notatum* were tested to determine the inhibition of growth of a number of species of micro-organisms. Special attention was paid to the genus *Klebsiella*, for the greatest variation in susceptibility to the bacteriostatic agent of *Pen. chrysogenum* was found in this genus, and consequently it was thought that any difference in biological activity might readily be

evident. The results, shown in Table II, indicate the agents of the two molds are biologically active only on the same bacteria.

TABLE II.

Inhibition of Growth of Bacteria by Culture Filtrates of Penicillium notatum and Penicillium chrysogenum.

Test Organism	Penicillium notatum	Penicillium chrysogenum
Klebsiella pneumoniae (Type A, A.T.C. 4208)	+*	+
Klebsiella pneumoniae (Type A, Jul., Rough)	+	+
Klebsiella pneumoniae (Type A, A.T.C. 6540)	−	−
Klebsiella pneumoniae (Type B, Gr. B.)	−	−
Klebsiella pneumoniae (Type B, calf heart)	−	−
Klebsiella pneumoniae (Type B, A.T.C. 4209)	−	−
Klebsiella pneumoniae (Type C, Jul.)	−	−
Klebsiella rhinoscleromata (R–83)†	+	+
Klebsiella rhinoscleromata (R–22–1)	+	+
Klebsiella rhinoscleromata (R–24–3)	−	−
Klebsiella rhinoscleromata (A.T.C. 4211)	−	−
Klebsiella rhinoscleromata (R–2)	−	−
Klebsiella ozanae (A.T.C. 4267)	−	−
Staphylococcus aureus (A.T.C. 4776)	+	+
Staphylococcus aureus (A.T.C. 6339)	+	+
Staphylococcus aureus (A.T.C. 6343)	+	+
Eberthella typhosa (H)	−	−
Salmonella typhimurium (A.T.C. 6993)	−	−
Proteus vulgaris	−	−
Pseudomonas aeruginosa	−	−

* + denotes inhibition of growth of the test organism.

DISCUSSION.

The similarity in the solubilities and absorption behavior of the bacteriostatic agents produced by *Penicillium chrysogenum* and *Penicillum notatum* indicates that these substances are chemically similar. The fact that the two substances form precipitates when treated with ferric salts confirms these indications. The practically identical biological activity is demonstrated by the inhibition of growth of a number of species of bacteria. Especially noteworthy in this regard is the identical behavior of the two agents on the various members of the genus *Klebsiella*, and the strains within the species *Klebsiella pneumoniae* and *Klebsiella rhinoscleromata*. It can be concluded that the bacteriostatic agents of these two molds probably affect the metabolism of susceptible bacteria by the same mechanism and that their chemical properties correspond closely.

BOOK REVIEWS.

ELEMENTARY PHYSICAL CHEMISTRY, by Merle Randall, Professor of Chemistry, University of California, and Leona Esther Young, Professor of Chemistry, Mills College. Photolithoprinted by Randall and Sons, Berkeley, California. xiv + 455 pp. Price, $4.50.

In presenting this new physical chemistry text, which is intended for use by second and third year college students, the authors have sought "to utilize the experiments performed in the elementary organic and quantitative laboratories as the basis of establishing the fundamental principles of modern thinking in this field." They assume that this may be "the text for the final formal study in physical chemistry for the large majority" of students and so have introduced freely "applications of particular interest to the analyst, the biologist, the biochemist, the engineer, and the geologist, believing that these applications will be of equal interest and value to the chemist and chemical engineer." The book "is also designed to give the foundation for succeeding or parallel courses in physical chemistry laboratory, advanced organic chemistry, colloid chemistry, photochemistry, phase rule, and chemical engineering."

The authors indicate that they have emphasized "modernized classical physical chemistry" because they believe that "a mastery of this portion of the field is an essential prelude to more advanced work" and it "is also the basis of a large proportion of the applications in the fields allied to chemistry." References to the newer aspects of physical chemistry, such as statistical mechanics and quantum theory, have been included in order that the reader may "correlate the older fundamental classical methods with the more modern viewpoints."

The book is lithoprinted and presents a neat appearance. The typing is clear and the paragraphing and the preparation of tables of data have been carefully done. The nearly 300 line drawings and other illustrations, each accompanied by several lines, in small type, of explanatory discussion, add greatly to the clarity of exposition and to the teachableness of the book. Numerous exercises and problems are given, not at the end of the chapters as is usual, but run into the text at intervals; several sets may appear in the same chapter. Apparently, not all of these are soluble upon information given in the text. Answers are not given.

The use of lithoprinting instead of the more conventional printing permits an informality of presentation which has some advantages in teaching. It permits, also, an incompleteness of treatment of certain topics which teachers of physical chemistry probably would not generally excuse in a more conventional text. Thus, terms are frequently introduced and used without the formality of definition or explanation. For example, we find used without definition such terms as *escaping tendency* (p. 28), *optical isomers* and *dextro-* and *laevo-rotatory* (p. 64), *solution* (p. 63), *critical point* (p. 81), *tautomeric* (p. 141), and *phase diagram* (p. 256). The omission of explanations of such terms would doubtless hamper the efforts of elementary students. The use of lithoprinting probably

also accounts for the total absence of the equilibrium sign, $\rightleftharpoons$, and of the reaction sign, $\rightarrow$; employing the equality sign, $=$, in their place, is not entirely satisfactory.

The selection of topics and the development of the subject-matter are not conventional but the authors succeed in driving home some of the most important general concepts of physical chemistry. Early in the book they introduce *fugacity* and use the concept freely thereafter. The development of the concept of *activity* in connection with gases and un-ionized solutes before there is any mention of ionic species will meet with the commendation of teachers of physical chemistry. Of less obvious advantage is the inclusion of material ordinarily taught in the elementary course in quantitative analysis such as that on *gas analysis* (p. 45), *quantitative standards* (p. 50), and the *Jones reductor* (p. 342), although the treatment of these topics is interesting and instructive. Many teachers of physical chemistry would prefer that the space occupied by the discussion of such topics were taken by other topics which they would expect to find in an elementary text and which appear only briefly or not at all. Thus, *reaction kinetics* and *catalysis* are greatly condensed; *adsorption* doesn't appear; *osmotic pressure* is referred to only in relation to other obligative properties of solutions; a few short paragraphs only are devoted to *colloids; liquefaction of gases, limiting density* and the *Victor Meyer method* apparently are not mentioned. On the other hand, certain topics, such as *vapor pressure* relationships, *thermochemistry, electromotive force* and *activity coefficients*, are excellently done.

The reviewer takes exception to the method of treatment of some topics and to the use of certain terms, although he admits that these points are, to some extent at least, debatable. (1) The representation of the hydrogen ion by H^+ and the representation of the ionization of an acid as the simple dissociation into H^+ and the anion seems unfortunate in view of the widespread acceptance of the reaction of the acid with the solvent to form hydrogen ion, H_3O^+ in the case of water as solvent, and the anion. In the same connection, there is no distinction drawn between "dissociation" and "ionization." Although it is difficult to be entirely consistent in the matter, it can hardly be considered to be a precise statement of the case to say that HCl "dissociates" in water solution; the term is more properly reserved for the mere separation of ions already present in the solute. (2) The use of the term *mol* as synonymous with *gram molecule* is not desirable; because of the confusion of *mol* with the abbreviation for *molecule*, the term *mole* is definitely preferable. (3) The representation of molarity by C and molality by M is not the usual practice; M and m, respectively, are more generally used. Also, there is strong implication (p. 78) that whereas *molarity* is a concentration unit, *molality* is something else. This will be confusing to the student. (4) The propriety of using *mol of electrons* synonymously with the *faraday* is questionable. The *mole* is a unit of mass and the *faraday* is "the number of electrons lost by a mol of sodium when it changes into sodium ion" (p. 55). There is evident here a lack of precision of statement. Furthermore, the consideration of the *electron* as an *element* (p. 321) seems highly fantastic and capable of leading to a serious misconception on the part of the student. (5) The meaning of *deliquesce* (p. 49) is not in accord with the accepted definition. A substance which is *hygroscopic* is not necessarily *deliquescent*. (6) The absolute definition of the *calorie*, i.e., 4.1883 joules, is not given. (7) The phase diagram

for water (p. 255) does not include *Ice VII* and the extension of the region of stability of the solid phase to over 100° C.

In spite of the fact that the book is somewhat limited in scope and in spite of the foregoing criticisms, the reviewer recommends it for careful study both as a reference source and as a textbook. It would seem to offer definite possibilities as a text for a review course in physical chemistry. It contains a great deal of value as a discussion of *fundamental principles*.

W. B. MELDRUM.

INTRODUCTION TO PHYSICS, by Harley Howe. 559 pages, illustrations, 16 × 24 cms. New York, McGraw-Hill Book Co., 1942. Price $3.75.

A mere recital of facts does not actually fulfill the purposes of a physics text. Any real appreciation of the subject must rest upon a knowledge of how scientists have applied fundamental laws and interpreted observations to reach accepted conclusions. The physics text should make such an analysis of the facts and in so doing acquaint the student with the application of the scientific method. This seems to be an underlying purpose of the author in presenting this textbook which follows a course in fundamentals for the college entrant.

The subject matter is divided into forty-five chapters. Generally the plan begins with mechanics including motion, work and energy, forces in solids, liquids and gases, and proceeds through vibrations and waves including sound, heat, electricity including electrons and radiation, and light. The text uses no mathematics beyond the elementary algebra and plane geometry mastered by college entrants. Considerable encouragement is given the student to question himself with regard to the text—even to the point of using certain phrases, with the belief that such questioning will lead to individual creative thinking and make more impressive the subject matter.

The book is profusely illustrated with diagrams and the plan includes in some places a so-called summary at the ends of chapters. These are not always outlines of work covered but merely statements especially designed to recall the high points. There is also, where advisable, a list of questions and a list of problems at the ends of chapters. While both are means for exercise, the former includes theory without actual use of mathematics and the latter requires application of both theory and calculations. In many instances the questions and problems are combined and, at least in a few, this combination is used not only as a means of exercise but to summarize the chapter. Answers are given to at least half of the problems, which is a point valuable to those who wish to use the text as a refresher or for home study.

The presentation here is logical and smoothly connected. It is up-to-date and covers an introduction adequate on which to build further study or for a general knowledge.

R. H. OPPERMANN.

MATHEMATICS OF MODERN ENGINEERING, by Ernest G. Keller. Volume II, 309 pages, illustrations, 16 × 24 cms. New York, John Wiley & Sons, Inc. and London, Chapman & Hall, Limited, 1942. Price $4.00.

This is volume two of what is intended to be a three volume set. The expressed purpose is to present those aspects of mathematics which the experience

of a large manufacturing organization (General Electric Co.), in dealing with electrical and mechanical investigations, has found to be of most value to engineers. A second purpose is to present an introduction to the methods of mathematical engineering by the analysis of discrete physical systems. Mathematical engineering consists of those parts of all branches of engineering which can be formulated mathematically, and by the analysis of discrete engineering systems is meant such problems as analyses of linear and non-linear networks, rotating electrical machines, airplane motions, vibration of motors, etc. After the physical phenomena are reduced to a mathematical system, mathematical engineering is employed in solution.

The treatment opens with engineering dynamics and mechanical vibrations where Hamilton's principle of mathematical physics is covered and proved by means of the study of the calculus of variations. After this, and under the same general heading, comes Lagrange's Equations, and a statement and proof of Rayleigh's principle for systems with a finite number of degrees of freedom. That is Chapter I.

The next chapter is an introduction to methods of reducing electrical engineering problems to mathematical form by means of tensor analysis and the theories of Kron. A preliminary non-mathematical description of the theories involved is first given, then a treatment of matrices and linear transformations precedes an introduction to tensor theory. Application is then directed to the solution of networks and rotating electrical machinery. The third, and last chapter, is devoted to the non-linear problem, one which when formulated mathematically, reduces to (one or) a system of differential, integral, or integro-differential equations such that at least one of the three quantities, a derivative, an integral, or a dependent variable, is involved transcendentally, or in some manner to a power higher than the first in at least one equation of the system. The theory is explained and application is made in the solution of practical problems in engineering.

The book reflects a careful selection of material for that which has direct bearing on the subject and the most usefulness. There is a good introduction to the new "mathematical engineering" which provides a better means for the solution of engineering problems.

R. H. OPPERMANN.

MOLECULAR FILMS, THE CYCLOTRON AND THE NEW BIOLOGY, by Hugh Stott Taylor, Ernest O. Lawrence, and Irving Langmuir. Essays, 95 pages, illustrations, 16 × 24 cms. New Brunswick, Rutgers University Press, 1942. Price $1.25.

This is number four of the Rutgers University publications of the one hundred seventy-fifth anniversary celebration. It contains three essays by outstanding scientists. Dr. Hugh Stott Taylor writes on Fundamental Science from Phlogiston to Cyclotron, outlining the progress of science over this period and especially emphasizing the interdependence of physics, chemistry, and biology. Molecular Films in Chemistry and Biology is the title of the essay of Irving Langmuir. Dr. Langmuir describes his technique with illustrations of results obtained and suggests ways of investigating biologocal problems, which have so far remained insoluble. A most spectacular tool of science is the cyclotron,

which is described here by Ernest O. Lawrence, its inventor. The work is profusely illustrated and Dr. Lawrence points out many of the things which will be investigated with this machine. The book provides interesting and instructive reading.

R. H. OPPERMANN.

PHYSICAL SCIENCE, by William F. Ehret, Leslie E. Spock, Jr., Walter A. Schneider, Carel W. van der Merwe, and Howard E. Wahlert. 639 pages, illustrations, 16 × 24 cms. New York, The Macmillan Company, 1942. Price $3.90.

A prerequisite to the culture of an educated man is a broad background of knowledge of the physical sciences. Our life of today is one which science has changed to something radically different from that of only a generation or two ago. Then, such scientific inventions as radio, the airplane, motion pictures, and the automobile were either unknown or bore no resemblance to what they are today. To appreciate the role of science in our civilization, the basic principles of pure science must be understood. It is with this thought in mind that the book at hand was constructed.

At the outset, the scientific method of studying a problem is emphasized, and its usefulness is pointed out for clear, logical, unbiased, and accurate thought in any field of human endeavor. In all there are twenty-five chapters, generally proceeding through the nature of matter, mechanics and heat, the atmosphere and weather, the elements of chemistry, geology, time wave motion, electricity, light, and sound. There are a large number of topics from the fields of astronomy, chemistry, geology, mathematics, and physics. It is especially shown how knowledge of one field is useful in another. The last chapter is devoted to a discussion on the nature of scientific reasoning, which is essentially an illumination of the truthfulness of scientific thought.

The book is profusely illustrated and well presented. The connection of subjects and logical progression is especially noteworthy. No hesitation is made to use mathematics in the text although there is no intent to furnish fundamental training to specialists or technicians in any of the fields covered. Rather, there is a happy medium between these to give the reader some appreciation of science.

R. H. OPPERMANN.

ISOMERIZATION OF PURE HYDROCARBONS, by Egloff, Gustav, George Hulla, and V. I. Komarewsky. 499 pages, illustrations, 16 × 24 cms. New York, Reinhold Publishing Corporation, 1942. Price $9.00.

The shift in the configuration of a molecule, without change in the number of atoms present, in the case of hydrocarbons, has a wide practical application in the petroleum industry. The tendency toward this is the result of the recognition that isomerization, by a mere change in spatial configuration of carbon and hydrogen atoms can produce selected hydrocarbons; the significance which the production of selected hydrocarbons has in aviation and, therefore, in national defense; and an appreciation of the fact that the anti-knock property of motor fuels, expressed in terms of "octane number," is a function of molecular structure. This monograph covers the isomerizations of pure hydrocarbons and gives both the qualitative and quantitative aspects of thermal and catalytic isomerizations.

Isomerizations are discussed for individual members of the groups: alkanes, alkenes, allenic alkadienes, non-allenic alkadienes, alkapolyenes, alkynes, alka-

diynes, alkapolyynes, cyclanes, cyclanes with saturated and unsaturated side-chains, spiranes, bicyclanes, bicyclanes with saturated and unsaturated side-chains, tricyclanes, pentacyclanes, cyclenes, cyclenes with saturated and unsaturated side-chains, cyclodienes with saturated and unsaturated side-chains, bicyclenes, bicyclodienes, tricyclenes, tetracyclenes, pentacyclenes, alkyl benzenes, alkenyl benzenes, allenic and non-allenic alkadienyl benzenes, alkapolyenyl benzenes, alkynyl benzenes, indanes, indenes, fluorenes, naphthalenes, anthracenes, phenanthrenes, naphthacenes, aromatic-cyclane hydrocarbons, aromatic-cyclene hydrocarbons, and aromatic-cyclodiene hydrocarbons. The available experimental data have been calculated to a uniform basis wherever possible. These are of value for the purpose of comparing catalyst concentration, time, temperature, pressure, and yield of products for more than 1700 experiments on isomerization shown in thirty-six tables.

Appendixes contain an extended translation of Moldavsky and Livschitz's fundamental work on iso-alkane determination, a translation of O. W. Bauer's Thesis, which also covers some fundamental work on iso-alkane determination but is interesting from the standpoint of quantitative estimation by means of physical methods based on "additive functions." The third appendix contains new material up to February 1, 1942, which is useful in a practical way in the construction and operation of plants producing isobutane from n-butane for the synthesis of 2,2,4 trimethylpentane or which can isomerize "ordinary gasoline" into aviation gasoline or its components.

As with other American Chemical Society Monographs, this one contains an extended bibliography and complete subject and author indexes. It is an invaluable work designed to be a direct contribution to progress in this field of endeavor.

R. H. OPPERMANN.

THE METHODOLOGY OF PIERRE DUHEM, by Armand Lowinger. 184 pages, 16 × 23 cms. New York, Columbia University Press, 1941. Price $2.25.

Those who are interested in the scientific method, its source, process, and results will find in this book a study of the remarkable ideas of Pierre Duhem, a man who has done important work in physics and the history of science. His ideas have influenced much logical thought in the United States. The detailed account herein begins with an orienting and non-technical introduction to the philosophy of science. Duhem's ideas on the nature of physical theory are exposed and on this are built his conceptions of the detailed processes which are involved in the building up of physical theory. First, the elements are selected and represented by algebraic or Geometric symbols, then the formulation of hypotheses accomplished by the process of mathematical deduction. The aim of physical theory, according to Duhem's conception, is stated as the representation and classification of experimental laws. Accordingly, there is given an exposition of his conception of the nature of experiment in physics and the theories of physical laws. From these are developed the principles governing the confrontation of experiment with theory. Here it is shown that it is impossible to construct a system of theory by the inductive method alone and that logic does not require that hypotheses should undergo, one by one, an experimental test, since isolated hypotheses cannot be tested, but only as a part of an extensive

system of theory. The selection of hypotheses is then discussed. Lastly, there are given critical remarks on Duhem's methodological ideas which have been outlined.

This is the first study in English of Duhem. It is interesting and thought provoking.

R. H. OPPERMANN.

PUBLICATIONS RECEIVED.

MATHEMATICS OF MODERN ENGINEERING, by Ernest G. Keller. Volume II, (Mathematical Engineering), 309 pages, illustrations, 16 × 24 cms. New York, John Wiley & Sons, Inc. and London, Chapman & Hall, Limited, 1942. Price $4.00.

BELL TELEPHONE SYSTEM, Monographs: B-1342, Greensalt—A New Preservative for Wood, by W. McMahon, C. M. Hill and F. C. Koch; and "Greensalt Treatment of Poles," by G. Q. Lumsden and A. H. Hearn. 28 pages, illustrations. B-1344, A Secondary Frequency Standard, by F. R. Stansel. 15 pages, illustrations. B-1345, Inspection in a Manufacturing Plant, by D. B. Keeling and L. E. Cisne. 14 pages, illustrations. B-1346, The Future of Transoceanic Telephony, by Oliver E. Buckley. 19 pages. B-1347, Entropy, by Karl K. Darrow. 24 pages, illustrations. B-1348, Diamond Dies for the High-Speed Drawing of Copper Wire, by H. N. Padowicz. 17 pages, illustrations. Six pamphlets, 15 × 23 cms. New York, Bell Laboratories, 1942.

ENGINEERING MECHANICS, by Frank L. Brown. Second edition, 503 pages, illustrations, 16 × 24 cms. New York, John Wiley & Sons, Inc., 1942. Price $4.00.

INDUSTRIAL CHEMISTRY, by Emil Raymond Riegel, Ph.D. Fourth edition, 861 pages, illustrations, 16 × 24 cms. New York, Reinhold Publishing Corporation, 1942. Price $5.50.

MICROWAVE TRANSMISSION, by J. C. Slater. First edition, 309 pages, illustrations, 16 × 24 cms. New York, McGraw-Hill Book Company, 1942. Price $3.50.

CURRENT TOPICS.

Electronic Speed Cop.—(*General Electric Review*, Vol. 45, No. 7.) The science of electronics may now supply the answer to the speeding motorist who tells the judge he did not know how fast he was going, according to Frazier Hunt, G-E newscaster. "Driving at night along a highway near St. Paul and Minneapolis (Minn.) the motorist's attention is caught by the sudden turning on of a large illuminated signboard ahead of him. A second or two later the sign flashes the speed of his car in lighted numbers big enough to be seen clearly by the driver. The sign also warns him of danger spot ahead and ample warning is thus given to permit him to bring his car to a safe speed before reaching this road junction. Startled by this electronic speed cop that issues no summonses, the motorist may wonder what mathematical genius is hiding behind the sign. The explanation is simple. As his car passes a certain point on the highway it interrupts a beam of invisible rays. A photoelectric relay turns on the sign, and starts an electronic timer which measures the car's speed. As the car passes a second electric eye the timer calculates the speed, and flashes the speed in lights, as a warning to the driver. Electrons, travelling with the speed of light, get the message on the signboard in plenty of time to warn the fastest driver. There is nothing to be gained by arguing with the speed shown on the sign. To an electron, one-millionth of a second is a long time. This application of G-E electronic devices is but another example of helpful public services which they can perform."

R. H. O.

The Theory of Probability Applied to Accidents.—D. C. STEWART (*Edison Electric Institute Bulletin*, Vol. 10, No. 7.) Probability, whether called by that name or not, has long been a useful tool in accident prevention. Mass statistics on past accidents, when carefully collected and analyzed, have yielded data by which the most probable sources of future accidents can be predicted. Any program based upon such studies embodies this simple but none the less important application of the principles of probability. Individuals tend to evaluate safety measures in terms of their experience of that of their immediate working group. Moreover, unless favorable habit patterns have been formed as a result of the individual's own experience, his present action may indicate clearly

that time has dulled the power of experience to influence action. The laws of chance are such that even the working lifetime of an individual or his group may not involve sufficient exposure to bring accident experience in line with underlying probabilities. A lineman who, for example, always wears working gloves when handling rough objects because his hand was once infected from a scratch may sense no inconsistency in working near live conductors without covering them or without wearing his rubber gloves simply because his fellow workmen and he have done so repeatedly with no ill effects. His first practice is sound but anyone who has carefully examined the records would estimate that odds are long on a fatality occurring from the second situation instead of the first. Supervisors charged with responsibility for accident prevention have an opportunity and a duty to determine underlying probabilities from study of accidents occurring in larger exposures, and to plan a program based upon the relative importance of those probabilities. Such a program rests, at least, upon a solid foundation. Beyond that, progress will depend upon the wise selection and effective employment of methods best calculated to mold the attitudes and convictions of men toward accident prevention so that they will pursue a favorable course of action in harmony with underlying probabilities.

R. H. O.

Laminated Timber Beams.—(*Engineering News-Record*, Vol. 129, No. 23.) Wartime steel scarcity which has drawn attention to glued, laminated timber beams, resulted in selection of this type of construction for a gymnasium in the new Recreation Center at Yesler Terrace in Seattle. The span here required was 67 ft. 2 in. By use of the timber beams some 20,000 lb. of steel was saved in addition to a cash saving. Each beam in the new gymnasium is 14 in. wide by 40 in. deep, built up of 3,900 b. ft. of 2 × 4 and 2 × 10 in. seasoned lumber. Two species of wood were used, Douglas fir and Sitka spruce. The Douglas fir, chosen for its strength, was placed in the outer edges of the beam where the stresses are highest; the spruce, of considerably lighter weight, was used in other portions of the beams. The beams were fabricated with butt joints on the inner laminations and scarfed joints in the outer layers. The glue, of which 135 lb. per beam was used, was of the self-bonding type for which sufficient pressure is obtained in each glued joint by the nailing operation for which 20d. nails were used. Both beams were put together with 3 in. camber of which only about ½ in. came out as the result of dead weight when

the beams were set in place. A full snow load on the roof would still leave 1 to 1½ in. of camber. Five and a half days were required for assembly of the two beams which were delivered from mill to job by logging trucks. The joint spacings in adjacent laminations were required to be not less than 40 times the lamination thickness with butted joints, and not less than 25 times the thickness with scarfed joints. All the material used was 1⅝ in. thick, the net dimension of 2 in. lumber surfaced on both faces.

R. H. O.

Brazilian Quartz—a Strategic Mineral.—PAUL F. KERR in *Mining and Metallurgy*, Vol. 23, No. 427, states that quartz of a certain kind is one of our strategic minerals, and Brazil is probably the one important available source. Crystals of quartz of suitable size and perfection for piezoelectrical application are rare; their most outstanding use is in radio work. Each broadcasting installation is equipped with crystal control. Apparently there is no feasible substitute for quartz in broadcasting control. Tourmaline has similar properties and has been employed, but clear tourmaline is not found in sufficient quantity. Tourmaline cut to the required thickness for standard controls must be much thinner and hence is apt to crack. Rochelle salts may be grown in large crystals but are unstable and subject to rapid deterioration under many conditions of use. The mechanical properties are also apt to be unsatisfactory. Synthetic quartz suitable for commercial use is still unrecorded. Although quartz occurs in many parts of the world, commercial material having been found in Madagascar, Alaska, and even in the United States, Brazil stands out preeminently as the commercial source. Large crystals from other localities have been used, but nowhere have they been found in sufficient quantity to even approach Brazil as a source of supply. Brazilian crystals are mined chiefly in Minas Geraes, Baia, and Goyaz, but they are widespread in occurrence and are found in other Brazilian states as well. The most important mining district is Fazenda Pacu, about 85 miles northwest of Belo Horizonte, the capital of the state of Minas Geraes. Here about 500 men are employed with picks and shovels removing quartz from a deeply weathered clay matrix. The ratio of good crystals to the discard is almost incredible, estimates at the mine running as high as one good crystal to 4000 rejected. Occasionally, large clear crystals weighing hundreds of pounds are found. One highly perfect individual weighing about half a ton arrived in New York from Brazil a little more than a year ago.

R. H. O.

Giant Flying Boats May Solve United Nations' Shipping Problem.—(*Heating, Piping and Air Conditioning*, Vol. 14, No. 9.) The entire flight deck and a large portion of the main deck of the Martin Mars, world's largest flying boat, is supercharged, permitting normal breathing without oxygen masks or tubes above the clouds, it has been revealed by the Glenn L. Martin Co. In addition, the entire crew enjoys at all times the benefits of heating, however high into the frigid atmosphere above the earth the giant plane may range. The supercharging of the mighty ship is done with an auxiliary engine that keeps the fore part of the ship pumped full of air. The engine pumping in air begins to operate at 8000 ft., where ordinary breathing is still easy. Although it was not feasible to supercharge the whole vessel, the entire interior is heated. The air drawn in passes over hot coils, which warm it to a comfortable temperature. Because of differences in air pressure within the hull when the ship is at high altitude it is necessary for a man moving from one end of the ship to the other to pass through a decompression chamber. This allows him to become accustomed gradually to the different atmosphere into which he is about to step. Oxygen stations are set up throughout the hull, which has a volume of a 15 room house, in case of emergency. Another interesting feature of the Mars is the 28 station telephone system that covers all points of the hull. A man can sit at his meal high above the clouds and receive or give orders between mouthfuls. In these ways, without sacrificing a bit of her efficiency in peace or in battle, the Mars makes her crew of 13 men as comfortable above the clouds as they would be on a surface vessel or on land.

R. H. O.

USDA Develops Process For Making Butylene Glycol From Farm Crops.—A short and economical process for making butylene glycol, a relatively rare chemical with several important commercial uses, was announced recently by the Department of Agriculture. The new method, being developed at the Department's Northern Regional Research Laboratory at Peoria, Illinois, involves the fermentation of plentiful farm crops, such as corn and wheat. The laboratory is now producing butylene glycol on a pilot plant or semi-commercial scale. It may be used in making anti-freeze for automobile radiators and in the production of commercial solvents. It has a number of industrial chemical applications for war industries. The laboratory is also studying butylene glycol as a possible link in the production of butadiene for synthetic rubber. Three steps would be involved in the production of rubber from agricultural crops by this method—raw material to butylene glycol,

butylene glycol to butadiene, and butadiene to rubber. The final step—production of synthetic rubber from butadiene—is, of course, already known. Considerable interest has been shown by industry in the fermentation process for producing butylene glycol. The major problem remaining is conversion to butadiene on a commercial scale. Chemists at the Peoria laboratory have succeeded in producing excellent yields of pure butadiene from corn-made butylene glycol in the laboratory, but they have not as yet developed the process to a pilot-plant scale and they are not making any definite predictions until this has been done.

R. H. O.

Ceramics.—A scientific industry as ancient as man yet as modern as today is coming into its own—and may yet prove to be one of the saviors of the American standard of living in this day when nothing short of an A-1 priority can buy even a tin can—according to one of its foremost Chicago exponents. He is DR. H. G. FISK, mineral technologist at the Armour Research Foundation, which is affiliated with and located at Illinois Institute of Technology. The industry is that of ceramics, which began as an art rather than a science centuries ago when primitive man first formed crude utensils from the clay around his aboriginal home. Dr. Fisk states that the ceramics of today is a far cry from those early clay dishes. Even before war took metals out of circulation, ceramic raw materials were involved in 70 per cent. of all industrial chemistry operations, they were fundamentally basic in the processing of most metals and an integral part of such sciences as radio and electrical engineering. Silicate products—principally glass—are the basis for a large portion of ceramic articles. Glass insulation was successful even before the war—but war's stimulus makes it almost a "must." Glass wool for example, used in insulating a battleship cuts down the weight by some 50 tons, and it is fireproof and vermin-proof. Another new use for glass is in marking airports and military highways. Tiny glass beads imbedded in the surface of markers reflect even a weak light into a guide for fliers or caravans. A second common and fundamental ceramic product is enamel, which today is experiencing a come-back as a replacement for aluminum. Aluminum once replaced enamel in the manufacture of kitchen utensils, hospital instruments and other common containers, and gained immediate popularity because of its greater lightness. Today's superior enamels, however, placed over a stronger and thinner base metal, rival even aluminum. Other ceramic products vital in today's industry are magnesium oxide, graphite, asbestos, quartz, kyanite and topaz.

R. H. O.